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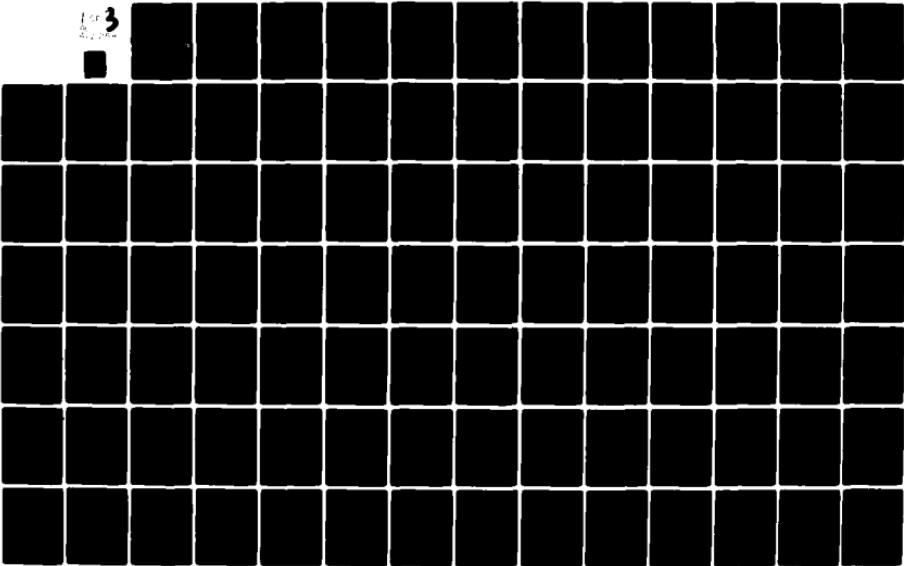
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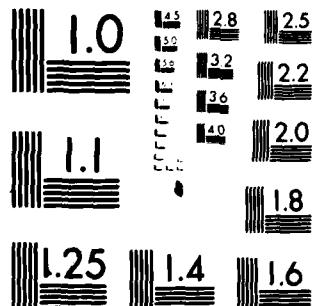
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DINS FINAL REPORT

Harris Corporation
Harris Semiconductor
P.O. Box 883
Melbourne, Florida 32901

19 October 1979

Final Report for Period 5 September 1978–19 October 1979

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This report summarizes the design effort on a photo detector assembly intended for use with a 6328-A optical input from a laser ggw system. The photodetector assembly shall consist of two chips: (1) photodiode chip and (2) preamplifier chip. The technology to be employed for fabrication of the chips is the D.I. linear technology.		

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TABLE OF CONTENTS

<u>Section</u>	<u>Page</u>
LIST OF ILLUSTRATIONS - - - - -	3
LIST OF TABLES - - - - -	4
1.0 INTRODUCTION AND SUMMARY - - - - -	5
2.0 DESIGN REQUIREMENTS - - - - -	6
3.0 TECHNICAL APPROACH - - - - -	7
3.1 Block Diagram Description - - - - -	7
3.2 Circuit Partitioning - - - - -	7
3.3 Gain Partitioning - - - - -	10
3.4 Dielectrically Isolated P+ -N- -N+ - - - - -	13
3.5 Process Description: Photodiode Preamp - - - - -	34
3.6 Radiation Effect Modeling - - - - -	49
3.7 Thermal Noise Analysis - - - - -	54
4.0 CIRCUIT DESCRIPTION - - - - -	57
4.1 General Overview - - - - -	57
4.2 Biasing - - - - -	60
4.3 Input Stages - - - - -	60
4.4 Active Loads and Gain Stages - - - - -	61
4.5 Output Stages and Short Circuit Protection - - - - -	61
4.6 Breadboard Simulation Results - - - - -	62
5.0 CONCLUSION - - - - -	64
Appendix - - - - -	65
1.0 MODEL PARAMETERS - - - - -	65
1.1 Pre-Radiation Parameters - - - - -	66
1.2 Post Neutron Parameters - - - - -	75
2.0 DC CIRCUIT SIMULATIONS - - - - -	79
2.1 Operating Points at 25°C (Pre-Rad) - - - - -	80
2.2 Operating Points at 125°C (Pre-Rad) - - - - -	92
2.3 Operating Points at -55°C (Pre-Rad) - - - - -	104
2.4 Operating Points Post Neutron - - - - -	116
3.0 AC and TRANSIENT SIMULATIONS - - - - -	129
3.1 25°C (Pre-Rad) - - - - -	130
3.2 125°C (Pre-Rad) - - - - -	150
3.3 -55°C (Pre-Rad) - - - - -	162
3.4 25°C (Post-Neutron) - - - - -	174

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TABLE OF CONTENTS (Continued)

<u>Section</u>		<u>Page</u>
4.0	NOISE SIMULATIONS - - - - -	181
4.1	Transient Gamma - - - - -	182
4.2	Thermal Noise - - - - -	186

LIST OF ILLUSTRATIONS

<u>Figure</u>		<u>Page</u>
1	System Functional Diagram	8
2	Bonding Requirements	9
3	Gain Partitioning	11
4	Computer Modeling	51
5	Prompt Gamma Recovery Time	53
6	Preamplifier Schematic	55
7	RF2, R31 Compensation Scheme	58
8	Breadboard Configuration	63

LIST OF TABLES

<u>Table</u>		<u>Page</u>
1	SNR vs Photodiode Volume Mismatch - - - - -	52
2	Table of Element Values - - - - -	56
3	Electrical Performance - - - - -	59

1.0 INTRODUCTION AND SUMMARY

This report summarizes the design of a radiation-hardened photodetector circuit by the Harris Semiconductor Programs Division for the Defense Nuclear Agency's DINS Program (Contract DNA 001-78-C-0356). The DINS photodetector is a two channel detector/amplifier which detects ring laser gyro optical signals (6328A). This is achieved by using three stages of signal conversion. The first stage is a photodiode which detects the incoming laser light signal and converts it to a small current. The second stage amplifies and converts this current to a small signal voltage. Finally, the third stage amplifies this small signal voltage to the output voltage level required.

Contained herein is a design description of the photodiode required for the photodetector. Reasons will be presented to explain the two die nature of the design. One die contains the input photodiodes plus large gain setting resistors while the second die contains the overall preamplifier circuit. Also following is the description of the preamplifier circuit which amplifies the output signal of the photodiode. Analyses of the proposed circuit have been performed by the SPICE II circuit simulation program which include DC, AC, Pre and Post radiation simulations over temperature and process variations.

The design effort is now complete and Harris is proceeding with the development of the DINS photodetector into topological design and prototype fabrication.

2.0 DESIGN REQUIREMENTS

The design requirements of the DINS photo detector system are enumerated as follows:

- The system shall receive a 300 nanowatt, (Min.) 6328 \AA signal from a ring laser gyro and convert it to a level in the hundreds of millivolts. It must do so in the presence of transient gamma radiation of the specification level and also after the exposure to neutron fluence of the specified level.
- The system shall have an adequate signal-to-noise ratio such that the input signal is not masked by the noise generated during a transient gamma event.
- Assuming the specified photodiode responsivity requirement of .44 Amps/Watt the preamplifier shall have a transimpedance gain of 3 megohms.
- The overall system bandwidth shall be a minimum of 1 megahertz.
- The preamplifier shall be capable of driving a capacitive load (i.e. coaxial cable).
- The preamplifier shall have short-circuit protection.
- A maximum of \pm 20 volts of supply voltage may be used.
- The operating temperature range shall be -55°C to $+125^{\circ}\text{C}$.

3.0 TECHNICAL APPROACH

3.1 Shown in Figure 1 is the overall system functional diagram of the DNS photodetector. The system has been divided into two chips, a photodiode chip and an amplifier chip. The photodiode chip also contains four 30K ohm resistors which set the gain of the first stage of amplification. A total of eight chip to chip bond wires shall be required and five bond wires shall be brought out to the package. (Figure 2).

3.2 Circuit Partitioning

In order to obtain a 1 to 1 or better signal to noise ratio under minimum drive conditions (300 nanowatts), it is necessary to reduce the noise as much as possible without sacrificing photodiode responsivity. The main noise contributors in the system are the photocurrents produced by the photodiodes during a transient gamma event. Although these photocurrents are applied common mode to the preamplifier by using an identical masked photodiode to the non-inverting input, any mismatch in these currents will be applied as a differential signal and therefore show up in the output as the major noise contributor.

Transient I_{pp} (primary photocurrent) is a direct function of the photodiode's total volume since the generation rate $g_E(\gamma)$ is linear with the depth of the island. However, the input laser signal is exponentially attenuated by the absorption coefficient of the material. Therefore it is the photodiode's area which will directly influence its responsivity. Based on these facts it is evident that the photodiode should have a thin structure with sufficient area for the required responsivity. In this way any mismatch in photocurrents will be minimized by minimizing the total photocurrent.

An island thickness of 2.54 μm was chosen to maintain a small total volume. However this would be incompatible with bipolar transistor fabrication. Therefore the two die approach shown in Figure 1 was chosen. The four 30K ohm resistors were chosen to go on the photodiode chip since their fabrication would be more compact using a higher sheet resistivity than the 250 ohm/square of the amplifier chip. A sheet resistivity of 1000 ohm/square will be used for these resistors.

SYSTEM FUNCTIONAL DIAGRAM

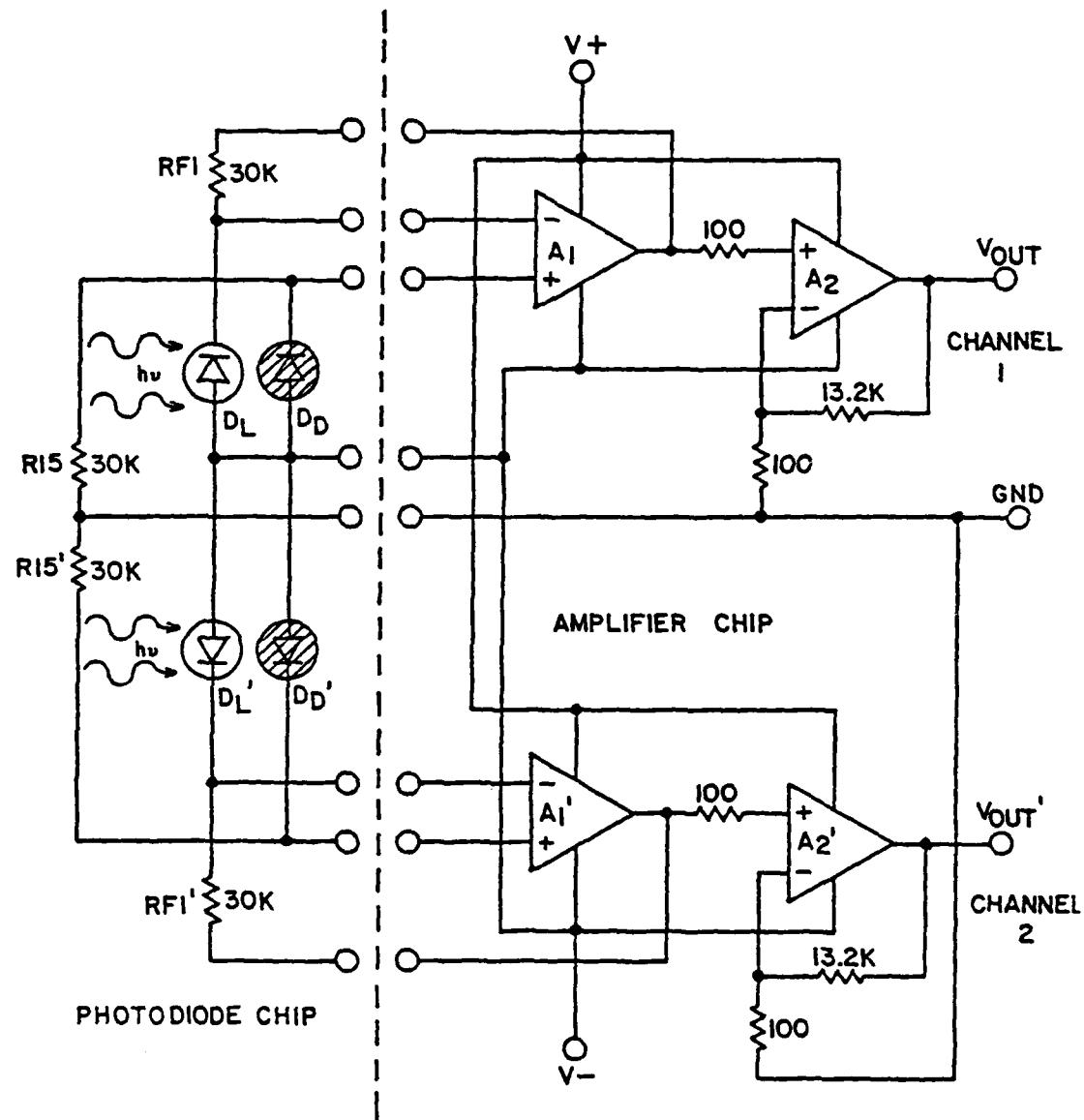


FIGURE 1

BONDING REQUIREMENTS

CHIP TO CHIP BOND WIRES

- Channel 1 Stage A, output to resistor R_{F1}
- Channel 2 Stage A, output to resistor R_{F1'}
- Channel 1 positive input to photodiode D_D and resistor R₁₅
- Channel 2 positive input to photodiode D_{D'} and resistor R_{15'}
- Channel 1 negative input to photodiode D_L and resistor R_{F1}
- Channel 2 negative input to photodiode D_{L'} and resistor R_{F1'}
- System ground
- System negative power supply V⁻

- = 8 Total chip to chip bonds

CHIP TO PACKAGE BOND WIRES

No bond wires are required from the photodiode chip.

From the amplifier chip are required:

- System positive power supply V⁺
- System negative power supply V⁻
- Output of channel 1 V_{Out}
- Output of channel 2 V'_{Out}

- = 5 Total chip to package bonds

FIGURE 2

3.3 Gain Partitioning

In designing a radiation-hardened preamplifier with an overall gain-bandwidth product as large as the one required here, it is important that adequate consideration be given to the distribution of the overall preamplifier gain. The gain of the preamplifier is 3 megohms of transimpedance under worst case temperature and process variability conditions. This worst case criteria also applies to the specified 1 megahertz bandwidth parameter. Process variability for both resistors and capacitors is $\pm 10\%$. The worst case gain situation will occur at low temperature combined with both low resistors and capacitors. This implies (from simulations) that a nominal element, room temperature gain of 4 megohms will be necessary. Likewise for bandwidth, a nominal figure of 2 megahertz was chosen to guard band against its worst case situation, which will occur at high temperature combined with both high resistors and capacitors.

Achieving a gain-bandwidth product of this magnitude is not feasible using only a single stage due to stability considerations. Therefore a two stage approach was chosen. Figure 3 shows the partitioning. The resistor names are those of the overall circuit. The value of transimpedance of stage A₁ (30K) and gain of stage A₂ (133) are values that require realistic gain-bandwidth products. Simulations show that under this configuration over 45° of phase margin can be obtained from each stage.

A second consideration is the amplifier's worst case input offset condition. The output level shift caused by this offset must still allow for the required maximum output voltage swing, which in this case is about half of a volt.

There are two types of offsets that can be generated at the inputs. Each stage has an inherent voltage offset due to V_{BE} mismatches in each respective input stage. This offset voltage appears at the output amplified by the voltage gain of the stage. In addition, beta degradation and mismatch post-neutron can cause currents (Figure 2) $I_{1(+)}$ and $I_{1(-)}$ to differ by as much as 20%. These currents which appear across the respective impedances seen at the input ports will generate an additional offset voltage which is

$$V_{OS} = I_{1(+)} \cdot R_{15} - I_{1(-)} \cdot R_{F1}$$

The DC voltage gain of transimpedance A₁ is unity. Therefore, this offset voltage appears at the output multiplied by the voltage gain of A₂ which is 133. This same current induced voltage offset will occur at the input of A₂, however here the impedances seen by the input differential pair is only about 100 ohms so the voltage generated across them is small.

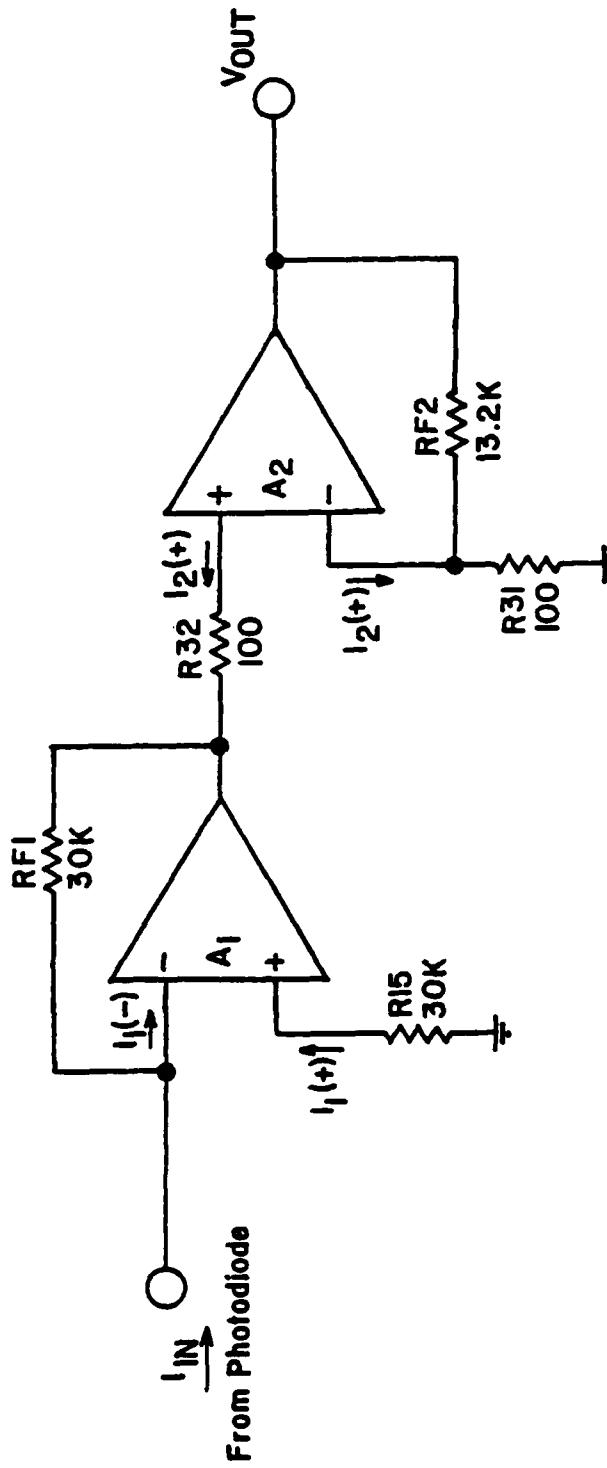
NPA betas may fall to 30 and PNP betas to 15 at the specified neutron level. Therefore:

$$\Delta I_1 \cdot R_{F1} = .44 \mu A \times 30K = 13.2 \text{ mV} \text{ (current induced offset)}$$

$$\Delta I_2 \cdot R_{31} = 2.4 \mu A \times 100 = .24 \text{ mV} \text{ (current induced offset)}$$

$$\begin{aligned} \Delta V_{IO_1} &\leq & 10 \text{ mV} \\ \Delta V_{IO_2} &\leq & \underline{10 \text{ mV}} \\ && 33.4 \text{ mV} \quad \text{Total } V_{IO} \end{aligned}$$

GAIN PARTITIONING
(ONE CHANNEL)



$$A_1 = 30K$$

$$A_2 = 133$$

OVERALL GAIN = 4 MEGOHMS

Figure 3

The total offset voltage multiplied by the voltage gain of the second stage brings the output voltage to 4.4 volts. Therefore a one half volt swing will not be a problem.

3.4

DIELECTRICALLY ISOLATED P+ - N⁻ - N⁺ PHOTODIODE3.4.1 Theoretical Analysis of Silicon P+ - N⁻ - N⁺ Photodiode for 6328 \AA Laser Detection.

3.4.1.1 Theoretical Analysis of Quantum Yield and Photocurrent:

The theoretical analysis of the photo response for a silicon p+ - n⁻ - n⁺ photodiode based on the structure shown in Figure 3.4.1a is presented in this report. The photodiode structure consists of a p⁺ implanted layer of about 0.15 μm thick, and n⁻ layer of 40-cm and 2.5 μm thick, and an n⁺ buried layer of about 2.5 μm .

The spectral response of the photocurrent and quantum yield for this photodiode is analyzed as follows:

Figure 3.4.1b shows a schematic diagram of the p+ - n⁻ - n⁺ photodiode under reverse bias conditions. Let us consider a He-Ne laser (6328 \AA) impinging on the p⁺ surface at y = 0. The rate of generation of photocarriers is given by

$$g_E(y) = \phi_0 (1-R) e^{-\alpha y} \quad (1)$$

where ϕ is the incident photon flux density, R is the reflection coefficient of silicon.

Under steady state conditions, the total photocurrent density, J_{ph} , produced by the incident photons is the sum of the electron and the hole current components at any cross section of the photodiode, which can be expressed by:

$$J_{ph} = J_n(y_0) + J_p(y_0) = J_n(y_0) + J_p(y_1) + J_i \quad (2)$$

where

$$J_i = J_p(y_0) - J_p(y_1) \quad (3),$$

In Eq. (2), $J_n(y_0)$ denotes the electron current density at y = y₀, $J_p(y_1)$ is the hole current density evaluated at y = y₁ and J_i is the component of the hole current density arising from the carrier generation in the intrinsic region (i.e., n⁻ - region). To find the function dependence of the photocurrent and the quantum yield, we need to express $J_n(y_0)$, $J_p(y_1)$, and J_i as functions of ϕ_0 , α , $(y_1 - y_0)$, and y_0 . Detailed derivation of the photocurrent in each of these three regions (i.e., $0 \leq y \leq y_0$, $y_0 < y < y_1$, and $y_1 < y \leq y_2$) have been given by Li and Lindholm [1] for a silicon p-i-n photodiode, which is applicable to the present case. Thus, the photocurrent density for a photodiode shown in Figure 3.4.1b can be expressed by (1):

$$J_{ph} = q\phi_0 (1-R) \left\{ -\frac{1}{\alpha L_n} \left[1 - \cosh \left(\frac{y_0}{L_n} \right) e^{-\alpha y_0} \right] \frac{1}{\text{Sinh} \left(\frac{y_0}{L_n} \right)} + \frac{e^{-\alpha y_1}}{1 + \alpha L_p} \right\} \quad (4)$$

and the quantum yield for the photodiode is given by:

$$n = \left| \frac{J_{ph}}{q\phi_0} \right| = (1-R) \left\{ \frac{1}{\alpha L_n \text{Sinh} \left(\frac{y_0}{L_n} \right)} \left[1 - \cosh \left(\frac{y_0}{L_n} \right) e^{-\alpha y_0} \right] - \frac{e^{-\alpha y_1}}{1 + \alpha L_p} \right\} \quad (5)$$

Equation (5) reduces to that of "Gartner's expression" if y_0 and R are set equal to zero {2}.

Now we can apply equations (4) and (5) to compute the photocurrent and quantum yield in a $p^+ - n^- - n$ photodiode shown in Figure 1. The specifications for the photodiode studied in this report are given as follows:

Diode Area: $A_j = 39.3 \text{ mil}^2 = 2.456 \times 10^{-4} \text{ cm}^2$

Junction Depth: $(p^+ - \text{Layer}) y_0 = 0.1 \mu\text{m} = 10^{-5} \text{ cm}$

Dopant Density: $n^- - \text{Layer} \rightarrow N_D = 10^{15} \text{ cm}^{-3}, \rho = 4 \Omega \text{cm}$

Thickness: $n^- - \text{Layer} \rightarrow y_1 - y_0 = 2.5 \mu\text{m} = 2.5 \times 10^{-4} \text{ cm}$

Buried Layer
($n^+ - \text{Layer}$)
Thickness:

$$y_2 - y_1 = 2.5 \mu\text{m} = 2.5 \times 10^{-4} \text{ cm}$$

Incident Photon Power Density: $P_{in} = 300 \text{nW}, \phi_0 = 3.89 \times 10^{15} \text{ Photons/cm}^2$

Incident Photon $\lambda_0 = 6328 \text{\AA} = 0.6328 \mu\text{m}$

Absorption Coefficient: $\text{at } \lambda_0 \text{ in Si} \Rightarrow \alpha = 3.5 \times 10^3 \text{ cm}^{-1}$

Hole Diffusion Length in n^- - Region: $L_p \cong 0.01 \text{ cm}$

Electron Diffusion Length In p^+ - Region: $L_n \cong 10^{-3} \text{ cm}$

Substituting the above listed numerical values for different parameters in Eqs. (4) and (5) yields:

$$J_{ph} = 0.543 \text{mA/cm}^2, \text{ and } n = 0.873$$

$$I_{ph} = 1.33 \times 10^{-7} \text{A for } P_{in} = 300 \text{nW}$$

The above results are obtained by assuming that the reflection loss is negligible at the surface of the photodiode.

Table 1 summarizes the calculated values of photocurrent, quantum yield and responsivity (assuming $R = 0$) of a silicon $p^+ - n^- - n^+$ photodiode for different junction depths (i.e., different thicknesses of the p^+ layer) with $P_{in} = 300 \text{nW}$.

Table 1. - Theoretical calculations of the photocurrent, quantum yield, and the responsivity of a silicon $p^+ - n^- - n^+$ photodiode for different junction depths (y_o). The incident laser beam (6328 Å) intensity is assumed equal to 300nW.

Junction Depth (y_o) μm	Photocurrent I_{ph} (nA)	Quantum Yield (n)	Responsivity (A/W)
0.10	133	0.873	0.44
0.15	132	0.865	0.44
0.20	131	0.856	0.437
0.25	130	0.848	0.433
0.30	128	0.84	0.426
0.40	126	0.825	0.42
0.50	124	0.809	0.413

It is noted that the above calculations are based on the assumptions that the reflection loss is negligible and the dopant densities in both p^+ - and n^- - layer are fixed. A change in the dopant density in both p^+ - and n^- - layer would in general change the quantum yield as well as responsivity of the photodiode.

3.4.1.2 ANTIREFLECTION (AR) COATINGS

In order to reduce the reflection loss at the silicon photodiode surface, it is important to incorporate the AR coatings in the design of photodiode. Theoretical considerations for the AR coatings in a silicon $p^+ - n^- - n^+$ photodiode are described as follows:

1.0. Single Layer AR Coating

To achieve a minimum reflection loss, a single layer dielectric film can be coated on top of the photodiode. Dielectric films commonly used in AR coatings include SiO_2 , SiO , Al_2O_3 , TiO_2 , Ta_2O_5 , and Si_3N_4 . To obtain minimum reflection loss, the thickness of the dielectric film can be chosen to be equal to quarter wavelength of the incident photon. For examples, if SiO_2 film is chosen, then

with $n_1 = 1.5$ for SiO_2 and $\lambda_0 = 6328\text{\AA}$, $d_1 = \lambda_0 = \frac{6328\text{\AA}}{4 \times 1.5} = 1055\text{\AA}$

If Si_3N_4 is chosen, then with $n_1 = 2.0$, $d_1 = \frac{6328\text{\AA}}{4 \times 2} = 781\text{\AA}$

The reflection loss can be calculated from

$$R_{\min} = \left[\frac{(n_1^2 - n_0 n_2)}{(n_1^2 + n_0 n_2)} \right]^2 \quad (6)$$

Where n_1 is the index of refraction of the dielectric film, n_0 is the index of refraction of air and n_2 is for silicon.

For the case of SiO_2 - Si system the reflection loss is only about 7% when 1100\AA SiO_2 is deposited on silicon photodiode. For Si_3N_4 - Si case reflection loss is only 0.016% if 800\AA Si_3N_4 AR coating is used!

The above theoretical calculations show clearly that the reflection loss in a silicon photodiode can be reduced to near zero by simply employing a single layer of dielectric film (i.e., SiO_2 , or Si_3N_4) as AR coating on the silicon photodiode.

2.0. Double Layer AR Coating

In addition to the single layer AR coating, one can also use double layer AR coating. In this case, two different types of dielectric film each with a quarter wavelength thick can be applied to the photodiode surface as AR coating. The minimum reflection loss can be calculated by using the expression:

$$R_{\min} = \left(\frac{n_1^2 n_3 - n_2^2 n_0}{n_1^2 n_3 + n_2^2 n_0} \right)^2 \quad (7)$$

Where n_0 is the index of refraction of air, n_1 is the index of refraction for the first AR coating layer and n_2 is for the second coating layer, and n_3 is the index of refraction for the silicon substrate.

If the thickness of SiO_2 and Si_3N_4 AR coatings were chosen to be $\frac{1}{4}$ wavelength of incident radiation, then the thicknesses of these two layers are given respectively by $d_1 = 1055\text{\AA}$ (for SiO_2) and $d_2 = 790\text{\AA}$ (for Si_3N_4), and the reflection loss calculated from Eq. (7) is 0.14 which is considerably higher than the single layer AR coatings calculated earlier.

Table 2. Summarizes the calculations of AR coatings for the silicon $p^- - n^- - n^+$ photodiode reported here.

Dielectric Film	Thickness a (Å)	Minimum Reflection Loss R _m (at 6328Å)	Refractive Index
SiO ₂	1055	7%	1.5
Si ₃ N ₄	781	0.016%	2.0
Ta ₂ O ₅	703	0.3%	2.25
SiO ₂ /Si ₃ N ₄	1055/781	14%	1.5/2.0

Table 2 - Single layer and double layer AR coatings for silicon p+ -n⁻ -n⁺ photodiode.

3.4.1.3 SUMMARY

In this report, we have shown theoretically that a responsivity of around 0.45 A/W can be achieved by using the proposed geometry and structure in the p+ -n⁻ - n⁺ silicon photodiode. The reflection loss can be minimized to a negligible level if a single layer dielectric film such as SiO₂ or Si₃N₄ with thickness equal to the quarter wavelength of the laser radiation is used as AR coating for the photodiode.

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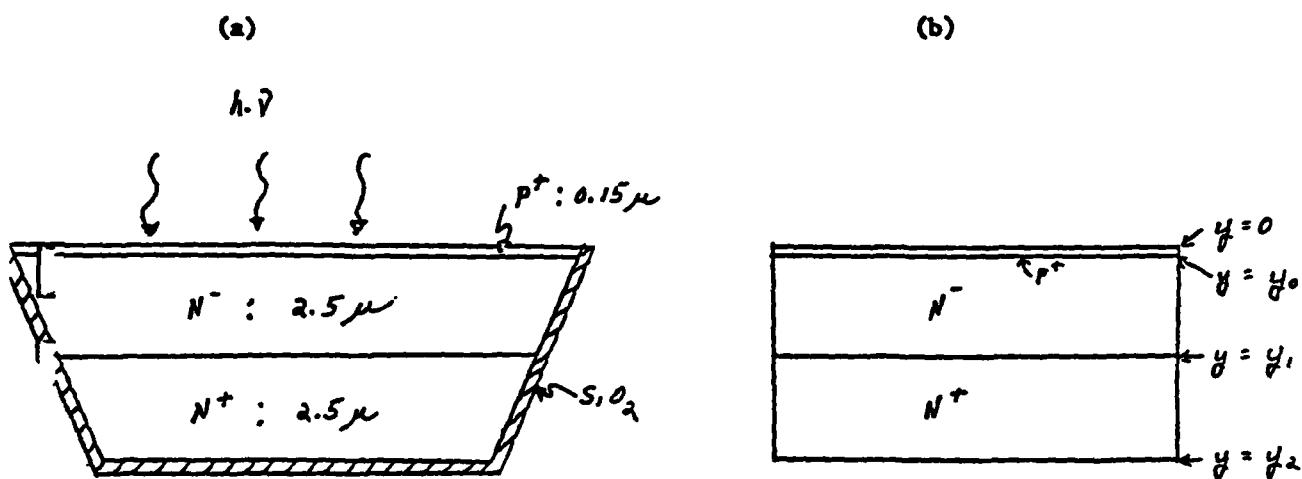


FIGURE 3.4.1. A SILICON $p^+ - n^- - n^+$ PHOTODIODE

(i) Reverse Leakage Current (I_R):

The reverse leakage current in the $p^+ - n^- - n^+$ photodiode can be calculated from

$$I_R = \frac{q n_i W_D A_j}{2t_i} \quad (1A)$$

Where n_i is the intrinsic carrier density, W_D is the depletion layer width, A_j is the junction area, and t_i is the carrier lifetime.

For large reverse bias ($V_j \leq -4.2V$), the depletion layer width is given by

$$W_D = W_N = 2.5\mu m$$

If $t_i \geq 100$ ns = 10^{-7} s, then

$$I_R = \frac{1.6 \times 10^{-19} \times 1.4 \times 10^{10} \times 2.5 \times 10^{-4} \times 2.456 \times 10^{-4}}{2 \times 10^{-7}} \\ = 6.877 \times 10^{-10} A \quad \text{at } 300K$$

(ii) Junction Capacitance of the $p^+ - n^- - n^+$ Photodiode

The junction capacitance for the $p^+ - n^- - n^+$ photodiode can be calculated from

$$C = \frac{A_j C_{jo}}{\left(1 - \frac{V_j}{\Phi_B}\right)^{\frac{1}{2}}} \quad (B1)$$

where

$$A_j = 2.456 \times 10^{-4} \text{ cm}^2$$

$$\Phi_B \approx \left(\frac{2kT}{q}\right) \ln \left(\frac{N}{n_i}\right) = 0.5756V$$

$$C_{jo} = \left(\frac{q \epsilon_s N}{2\Phi_B}\right)^{\frac{1}{2}} = 1.2 \times 10^{-8} \text{ F/cm}^2$$

$$C_j = \frac{3.1}{(1-1.75 V_j)^{\frac{1}{2}}} \text{ PF} \quad (B2)$$

where V_j is the bias voltage.

For example :

at $V_j = -10V$, $C_j = 0.72\text{pF}$.

The capacitance due to SiO_2 isolation around the photodiode can be estimated by

$$C_I \approx \frac{A_I \epsilon_{\text{ox}}}{t_{\text{ox}}} \quad (\text{B3})$$

where $\epsilon_{\text{ox}} = 4$, $A_I = 2.775 \times 10^{-4} \text{ cm}^2$, $t_{\text{ox}} = 1.8\mu\text{m}$

$$C_I = 0.546\text{pF}$$

(iii.) Gamma Radiation Current (I_{pp})

The gamma radiation current can be calculated from the following expression:

$$I_{pp} \approx g_0 A_j (W_p + L) \dot{\gamma} \quad (\text{C1})$$

where $g_0 = 4 \times 10^{13} / \text{Rad}$

For the $p^+ - n^- - n^+$ photodiode considered, $W_p = W_n = 2.5\mu\text{m}$, the effective diffusion length in the buried layer is essentially the thickness of this layer (W_{BL}), thus

$$L \approx W_{BL} = 2.5\mu\text{m}$$

and

$$I_{pp}/\dot{\gamma} = 0.81 \text{ PA/rad/S}$$

If $\dot{\gamma} = 10^7 \text{ Rads/S}$ then

$$I_{pp} = 8.1\mu\text{A}$$

3.4.2

TOPOLOGICAL DESIGN OF A SILICON p⁺ - n⁻ - n⁺ PHOTODIODE

A test chip was designed with various geometry photodiodes to determine an optimum performance design compatible with existing process capabilities. Three pairs of diodes were designed on the test chip; a pair consisting of an open diode for detecting a 6328 \AA He-Ne laser and an identical geometry dark diode, masked from the laser with aluminum, for radiation photocurrent compensation. This section describes the three designs and the advantages and disadvantages of each.

Photodiode Design #1: Stepped D.I.

Figure 3.4.2 shows the stepped D.I. design. The dielectric isolation pattern of this design was stepped, anticipating that the natural corner rounding which occurs during the anisotropic silicon etch (moat etch) would result in a circular shaped island. However the etch time required to etch the shallow island (0.2 - 0.3 mil) resulted in only minimal corner rounding. As a result, the final island geometry closely replicates the drawn island geometry as shown in the design.

The anode is a 5.0 mil radius semicircle with 0.2 mil spacing between the anode aperture and the minimum D.I. island. P⁺ contact to the anode is made via a 0.6 by 9.0 mil aperture along the diameter of the semicircle. The N⁺ contact to the cathode is a 0.6 by 0.6 mil aperture spaced 0.3 mil from the anode aperture.

Photodiode Design #2: Stepped D.I. with N⁺ Ring

The stepped D.I. with N⁺ ring design is shown in Figure 3.4.3. Additional steps were added in the dielectric isolation pattern to determine if the corner rounding effect with the additional steps would result in a more uniform semicircular pattern. However as in the previous design the minimal required etch time resulted in the final island geometry being very similar to the design island geometry.

The anode of this design is identical to the previous design.

A 0.4 mil N⁺ ring spaced 0.3 mil from the anode was designed for the cathode contact. This ring provides a lower resistance cathode contact to enhance the efficiency of the diode. The disadvantage of this design is that the addition of the N⁺ ring increases the total island volume over the previous design which could result in an increase in radiation induced photocurrent. The trade-off to be evaluated then is improved photodiode performance vs. radiation hardness.

Photodiode Design #3: Circular D. I. Island

The circular D.I. island design is shown in Figure 3.4.4. This design was included to study the feasibility of anisotropically etching a circular pattern at the dielectric isolation photoresist and moat etch process steps.

No significant problems were encountered on the first run at the D.I. photoresist and moat etch steps. In fact the final island geometry was very close to the designed geometry.

The anode, anode contact and cathode contact were identical to Design #1.

PHOTOVOLTAIC DESIGN # 1

STEPPED D.I.

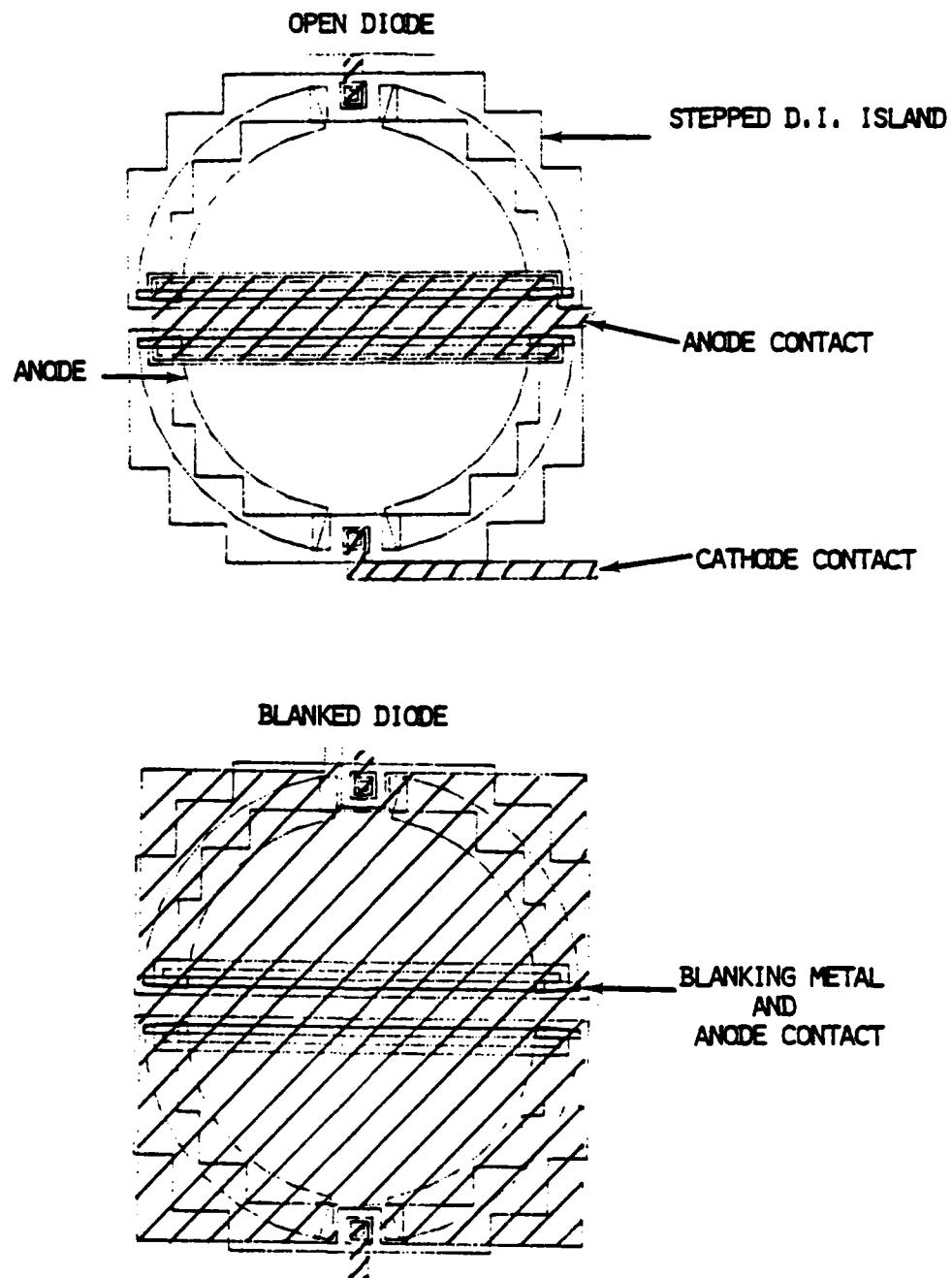


Figure 3.4.2

PHOTODIODE DESIGN #2
STEPPED D.I. & N+ RING

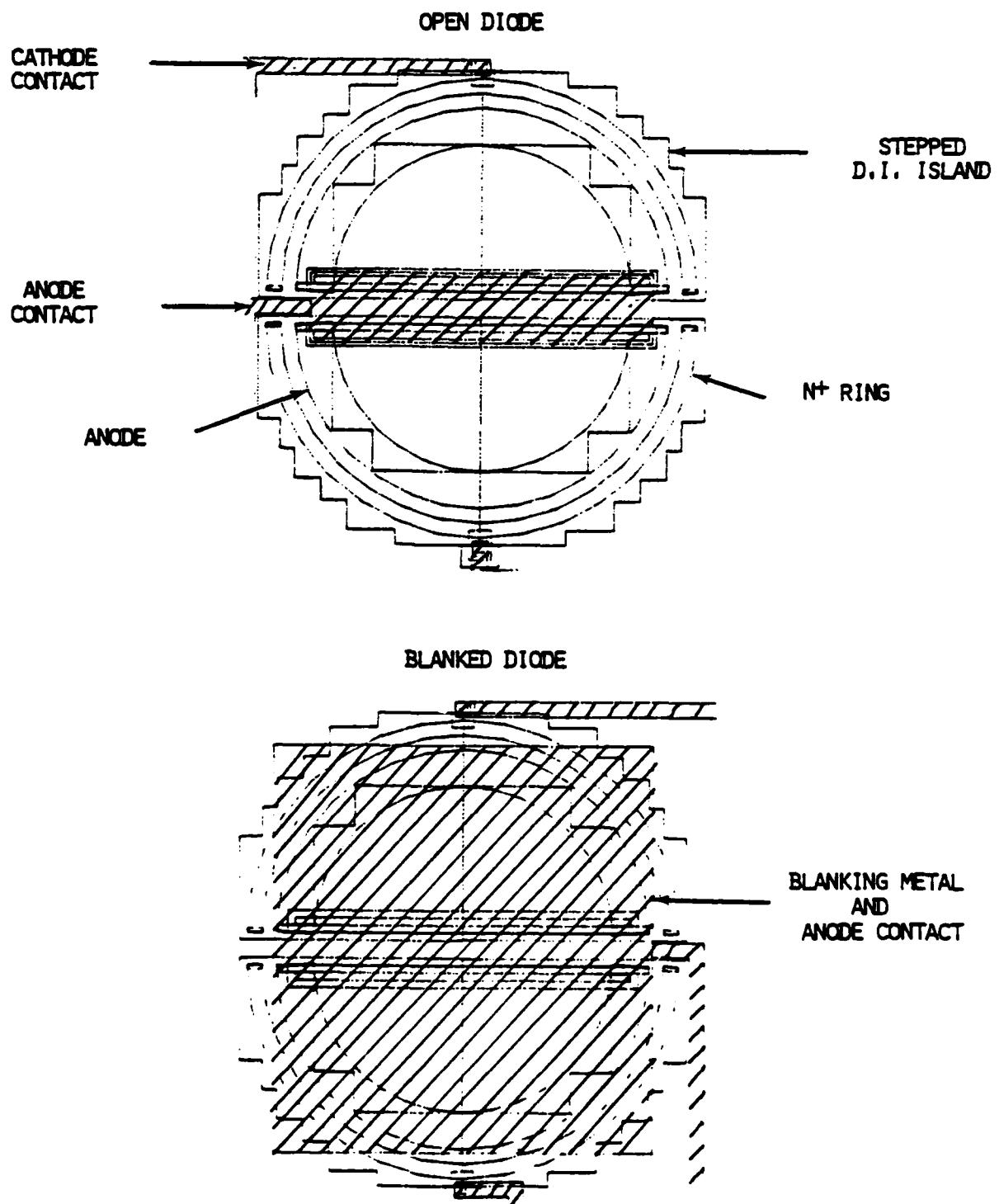


Figure 3.4.3

PHOTODIODE DESIGN #3
CIRCULAR D.I. ISLAND

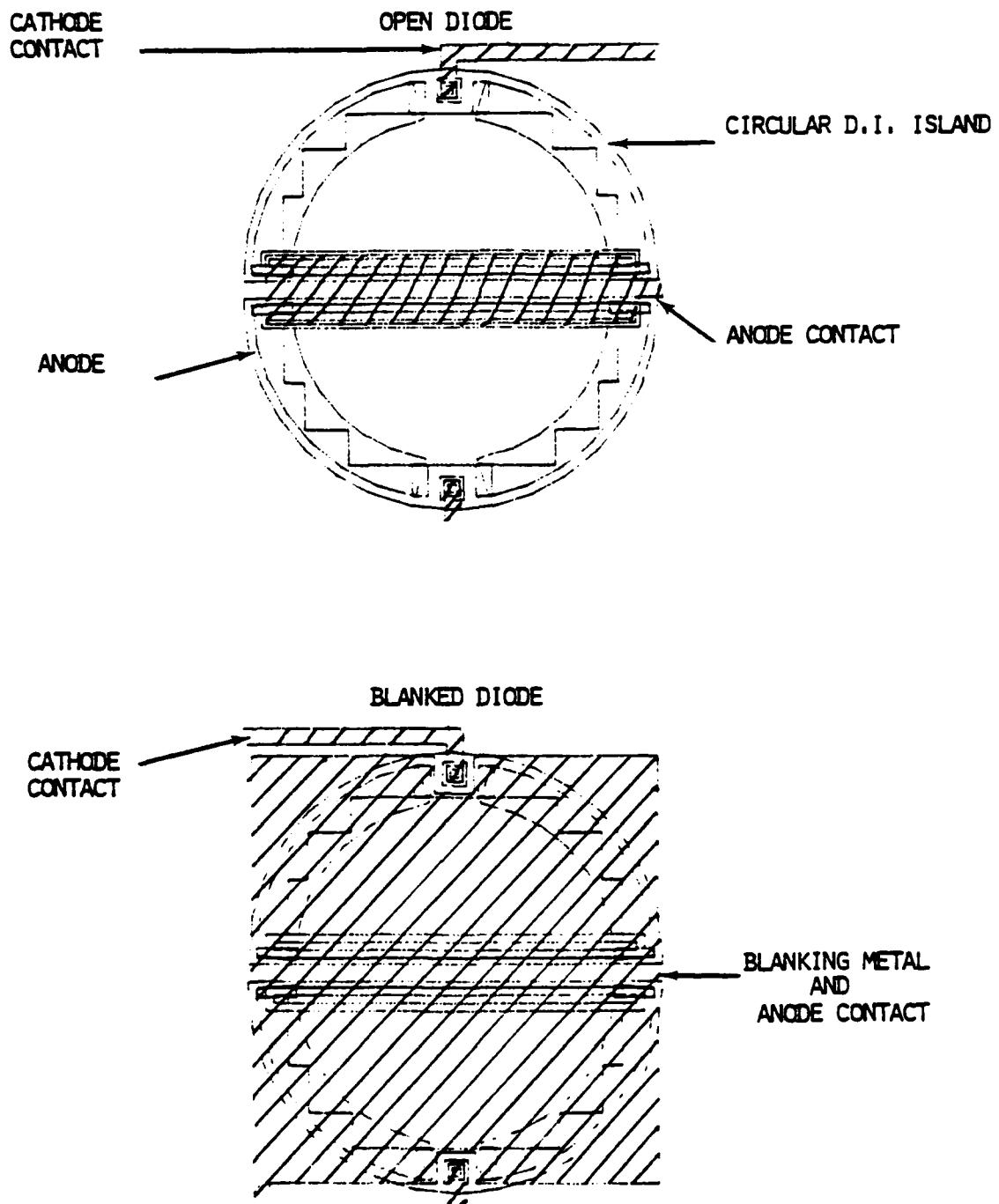


Figure 3.4.4

3.4.3 Process Description

This section describes the process employed to fabricate the photodiodes. Both the dielectric isolated materials process and the frontside wafer fabrication process will be described as well as the process permutations employed on the first run of photodiodes.

3.4.3.1 Materials Fabrication Process

1.0 Starting Substrate:

Resistivity: 3-5 ohm-cm N-type

Orientation: <1-0-0>

Background Concentration: $\sim 10^{15} \text{ cm}^{-3}$

Diameter: 3 - inch

2.0 Buried Layer Formation:

After the buried layer pattern is defined in the field oxide, the buried layer is formed via a two step ion implantation and diffusion operation. The final buried layer process parameters are:

$$\rho_s \approx 25 \text{ ohms/sq.}$$

$$x_j = 2.5 \mu$$

$$C_s \approx 4 \times 10^{19} \text{ cm}^{-3}$$

3.0 Dielectric Formation:

The dielectric isolation is delineated in the field oxide followed by an anisotropic silicon etch to form the isolation moats. The precise geometry of the moats is defined by the isolation photoresist pattern and the fact that the etch proceeds down the <1-1-1> plane. Following the moat etch, the dielectric oxide is thermally grown.

$$t_{ox} = 1.0 \mu$$

4.0 Polycrystalline Silicon Deposition:

The polycrystalline silicon is chemically vapor deposited to achieve the final substrate thickness of ~ 25 mils.

5.0 Final Polish:

The wafers are then chemically-mechanically polished to the specified isolated island thickness of 5 - 7.5 microns.

3.4.3.2 Wafer Fabrication Process

1.0 Initial Oxidation:

The first step in the wafer fabrication process is a thermal oxidation to grow the field oxide followed by a crystal anneal to anneal out the mechanical polish damage.

$$t_{ox} = 0.4 \mu$$

2.0 N^+ Cathode Contact:

Following a photoresist operation to delineate diffusion apertures to the n^- cathode, the n^+ cathode contact is formed by a two step phosphorus predeposition and diffusion operation. This process results in the following parameters:

$$\rho_s = 10 \text{ ohms/sq.}$$

$$x_j = 2.5 \mu$$

$$C_s = 3.0 \times 10^{20} \text{ cm}^{-3}$$

3.0 P^+ Anode Contact:

After the P^+ aperture pattern is etched in the field oxide, the P^+ anode contacts are formed with a two step boron predeposition and diffusion process. The resulting parameters are:

$$\rho_s = 125 \text{ ohms/sq.}$$

$$x_j = 0.6 \mu$$

$$C_s = 4.0 \times 10^{19} \text{ cm}^{-3}$$

4.0 Anode Formation:

A 5 mil radius circular pattern is etched in the field oxide for the anode of the photodiode. Subsequent to the etching operation, 1100 \AA of thermal oxide is grown in the opened anode area. This oxide serves to control the peak of the anode ion implantation. Boron is then ion-implanted to form the p^+ anode. The following are the ion implantation parameters:

$$\text{Energy} = 100 \text{ KeV}$$

$$\text{Dose} = 2.3 \times 10^{-3} \text{ coul.}$$

$$\text{Projected Range} = 0.12 \mu$$

$$\text{Peak Concentration} = 2.5 \times 10^{19} \text{ cm}^{-3}$$

5.0 Antireflection Coating and Si_3N_4 Passivation:

If a silicon nitride AR coating is desired, then the 1100 \AA of thermal oxide is removed from the anode area and 800 \AA of silicon nitride is chemically vapor deposited over the wafer. If an SiO_2 AR coating is preferred, then the 1100 \AA of thermal oxide is left over the anode and the 800 \AA of silicon nitride is later etched from the anode area, exposing the 1100 \AA SiO_2 AR coating.

6.0 Contact Apertures:

The contact aperture pattern is plasma etched in the silicon nitride and the underlying thermal oxide is dipped out creating the anode and cathode contact apertures.

7.0 Interconnect Formation:

A 1.2 μ thick aluminum/2% silicon film is sputtered over the wafer and the interconnect pattern is then delineated in this film.

8.0 Passivation and Backlap:

An 8000 \AA film of SiO_2 is chemically vapor deposited over the wafer to serve as a passivation layer. The bond pad pattern and the anode of the photodiode is etched in the passivation oxide. The wafers are then thinned to the final die thickness of 11 mils.

3.4.3.3 Vertical Cross-Section

Figure 3.4.5 depicts the vertical cross-section of the dielectrically isolated photodiode.

3.4.3.4 Process Permutations

To establish an optimum process for the photodiode fabrication, several process permutations were employed on the 1st run.

3.4.1.0 Buried Layer vs. No Buried Layer:

Wafers 1 - 10: Buried Layer

Wafers 11 - 20: No Buried Layer

3.4.2.0 Antireflection Coating:

Even numbered wafers: Silicon nitride AR

Odd numbered wafers: Silicon Dioxide AR

3.4.3.0 Crystal Anneal:

Anneal #1: Wafers 6-10 and 16-20

Ramped initial oxidation and anneal

Anneal #2: Wafers 1, 2, 11 and 12

Harris standard initial oxidation and anneal

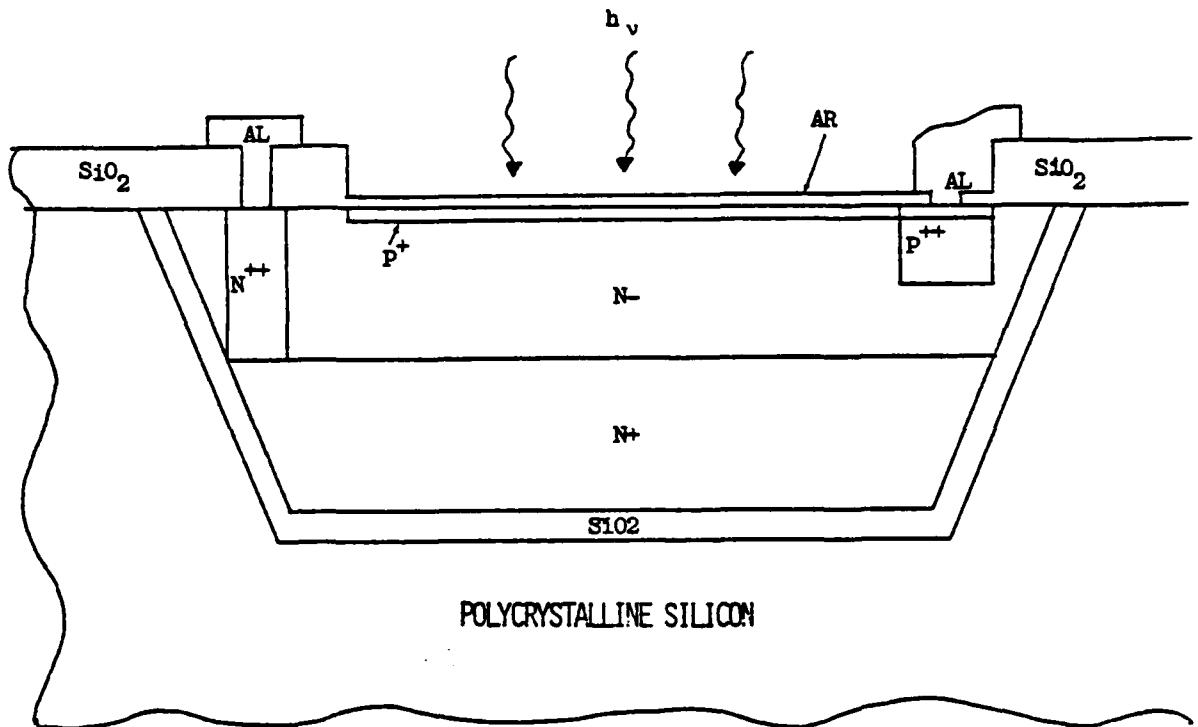
Anneal #3: Wafers 3, 4, 5 and 13, 14 and 15

Harris standard initial oxidation with no anneal

3.4.4.0 Preliminary Results

The responsivity and dark currents with and without radiation and the photocurrent generation constant of the various process permutations were evaluated by Honeywell personnel. This section summarizes the results of those evaluations.

IDEALIZED VERTICAL STRUCTURE
OF PHOTODIODE



N^+ Buried Layer

$$C_s \approx 1.0 \times 10^{19} \text{ cm}^{-3}$$

$$N^+ \text{ thickness} = 2.5\mu$$

N^- Layer

$$C_B \approx 1.0 \times 10^{15} \text{ cm}^{-3}$$

$$N^- \text{ Thickness} = 2.5\mu$$

P^+ Anode

$$C(\text{Peak}) \approx 2.5 \times 10^{19} \text{ cm}^{-3}$$

$$\bar{R}_p = 0.12\mu$$

P^{++} Anode Contact

$$C_s \approx 4.0 \times 10^{19} \text{ cm}^{-3}$$

$$P^{++} \text{ Penetration} = 0.6\mu$$

N^{++} Cathode Contact

$$C_s \approx 3.0 \times 10^{20} \text{ cm}^{-3}$$

$$N^{++} \text{ Penetration} \approx 2.5\mu$$

Figure 3.4.5

3.4.4.1 Responsivity

Table 3.4.1 summarizes the average responsivity results for the various processes for the circular design and the N⁺ cathode ring design before and after exposure to gamma radiation. The responsivity was calculated as follows:

$$R = \frac{\text{Amp}}{\text{Watt}} = \frac{\text{current out} - \text{dark current}}{\text{Watts}(6328\text{\AA}) \text{ in}}$$

where the input power of the He Ne laser was approximately one μ watt. From this data it appears that the N⁺ ring design with a silicon nitride AR coating (wafer #8) is optimum. Comparing wafer #8 (Si₃N₄ AR with buried layer) with wafer #18 (Si₃N₄ AR without buried layer) it appears that the presence of the buried layer has little effect on responsivity. The most notable processing effect on responsivity is the AR coating, with the Si₃N₄ AR coating (even numbered wafers) resulting in a higher responsivity than the SiO₂ AR coating.

3.4.4.2 Differential Responsivity

Differential responsivity is defined as the responsivity difference between the unmasked and masked photodiodes. Table 3.4.2 summarizes the results of these measurements. Again the results show that the N⁺ ring design and the wafer #8 process is optimum.

3.4.4.3 Dark Current

The dark is the reverse bias leakage current measured at -10V on the anode. Table 3.4.3 summarizes the results of the dark current measurements. All diodes displayed less than 10 nA dark current.

3.4.4.4 Photocurrent Generation constant

Table 3.4.4 summarizes the empirical results of the photocurrent generation constants for the two designs and the various process permutations.

3.4.4.5 Photocurrent Balance

In general, the photocurrent balance between the masked and unmasked diodes was poor - greater than 10% in some instances. It was also found that the balance was sensitive to total ionizing dose. Modifications to the design and further characterization of the material and process have been initiated in an attempt to improve the balance.

**Average Responsivity In Amps Per Watt of Diode
With and Without Gamma Radiation From Columns A + B**

Wafer #	Gamma Radiation Circular	No Radiation Circular	Gamma Radiation N + Ring	No Radiation N + Ring
I	---	.238	---	.310
8	.382	.261	.439	.312 *
II	.264	.205	.303	.249
15	.294	.264	.357	.344
17	.268	.294	.273	.284
18	.321	.375	.419	.426

- * The diodes in package 7 appear to be marginally functional. Excluding their data this number would be 463.

TABLE 3.4.1

Average Responsivity Per Wafer In
Amps Per Watt From Columns E & F

<u>Wafer #</u>	<u>Circular Diode</u>	<u>N + Ring Diode</u>
1	.235	.343
8	.338	.440
11	.236	.258
15	.271	.318
17	.267	.261
18	.392	.403

TABLE 3.4.2

Average Dark Currents In 10^{-10} Amps of Diodes With
and Without Gamma Radiation

Wafer #	Gamma Radiation Circular	No Radiation Circular	Gamma Radiation N + Ring	Gamma Radiation N + Ring	No Radiation N + Ring
1	---	97	----	40	
8	17	33*	94**	8	
11	11	5	9	0	
15	7	7	5	4	
17	62	1	16	56***	
18	75	6	13	8	

- * Without package 8 diode 4 this number would be 4.
- ** Without package 5 diode 3 this number would be 9.
- *** Without package 24 diode 1 this number would be 7.

TABLE 3.4.3

PHOTOCURRENT GENERATION CONSTANT

WAFER #	GENERATION CONSTANT (X10 ¹³ COUL/RAD)	
	N ⁺ RING DESIGN	CIRCULAR DESIGN
1	5	6.9
8	5.2	5.3
11	5.5	6.3
15	10	9.5
17	4.1	4.8
18	7.2	8.0

TABLE 3.4.4

3.5 PROCESS DESCRIPTION: PHOTODIODE PREAMP

The preamp uses a standard Harris linear process featuring dielectric isolation, complementary NPN/PNP devices, MOS capacitors and implanted high sheet resistors. The process description will be divided into a material fabrication section and a frontside processing section. Material fabrication covers the sequence from starting material to slice grind and polish, frontside processing covers initial oxidation through backlap.

1. MATERIAL FABRICATION. This sequence is outlined below.

Initial Oxidation
P Collector Photoresist and Etch
P Collector Diffusion
N+ Buried Layer Photoresist and Etch
N+ Buried Layer Diffusion
Isolation Photoresist and Etch
Anisotropic Moat Etch
Isolation Oxidation
Polycrystalline Si Deposition
Front Side Lap and Polish

- Initial oxidation grows a masking oxide on the polished slice. Starting resistivity is 3-6 ohm-cm; orientation is 1-0-0; slide diameter is 3"; and slice thickness is 20 mils.
- P collector photoresist/etch defines collector areas for PNP devices.
- P collector diffusion establishes a deep, lightly doped boron diffusion for use as a PNP collector. (Figure 1).
- N+ buried layer PR and diffusion establishes a heavily As doped layer used as a low resistivity subcollector for the NPN devices. (Figure 2).
- Isolation photoresist defines the isolation grooves.
- Isolation etch is anisotropic; the etch will stop on the 1-1-1 plane and hence the groove depth is defined by its width. (Figure 3).
- Isolation oxidation is performed next; oxide thickness is 1.8 μ nominal for defect density reduction. See Figure 4.
- Polycrystalline silicon is then deposited to a thickness of approx. 25 mils. This poly forms the substrate of the dual slice. (Figure 4).
- The original single-crystal slice is then ground away and the resulting structure is polished. The result is a largely polycrystalline slice with isolated regions of single-crystal Si. Note that both P and N type regions are available and that the N region also was an N+ buried layer. The slice has completed material fabrication at this point. Figure 5 illustrates the finished structure.

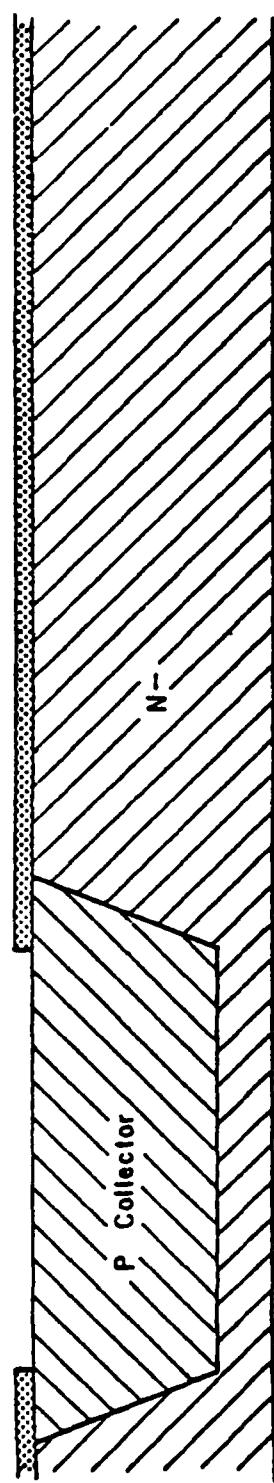
2. FRONTSIDE PROCESSING. Sequence is given below.

High Temperature Crystal Anneal
N-Base Photoresist and Oxide Etch
N-Base Diffusion
P-Base Photoresist and Oxide Etch
P-Base Diffusion
P-Emitter Photoresist and Oxide Etch
P-Emitter Diffusion - PNP Transistor Beta Piloted
N-Emitter Photoresist and Oxide Etch
N-Emitter Diffusion - NPN Transistor Beta Piloted
Capacitor Photoresist and Oxide Etch
Capacitor Low Temperature Oxidation
Implanted Resistor Photoresist and Oxide Etch
Resistor Low Temperature Oxidation
Resistor Implantation
Contact Photoresist and Oxide Etch
Sample Probe
Aluminum Evaporation
Aluminum Photoresist and Metal Etch
SiO₂ Deposition
Contact Base
SiO₂ Photoresist and Oxide Etch
Stabilization Base
Sample Probe
Backlap

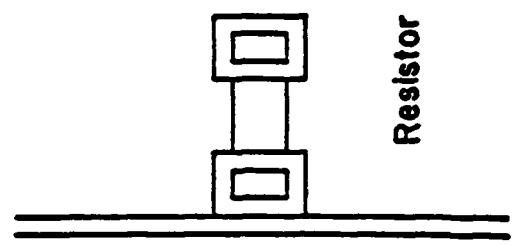
- A high temperature crystal anneal follows the 1100° initial oxidation; it stabilizes the structure and reduces defects.
- N base PR and diffusion establishes the PNP base. (Fig. 6).
- P base PR and diffusion establishes the NPN base. (Fig. 7).
- P+ PR and diffusion completes the PNP device; a piloting procedure controls device beta. Contact regions for the NPN base and PNP collector are also formed at this step. (Fig. 3).
- N + PR and diffusion completes the NPN device; again, piloting controls NPN beta. PNP base and NPN collector contact regions are also formed. (Fig. 9).
- Capacitor photoresist opens the capacitor dielectric area located over a P + diffusion used for the lower capacitor plate. A low temperature oxidation is then used to grow a precisely controlled oxide layer of 2000 Å nominal thickness. (Fig. 10).
- The implanted resistors are defined next; a thin oxide layer is grown in the resistor geometries.
- The resistor is implanted using an 80 keV boron implantation. Note the resistor end caps are P +; also the boron implantation is through a thin oxide to prevent excessive surface damage. Figure 11 gives the resistor structure. Nominal sheet resistivity is 1000 ohms/square.

-2- FRONTSIDE PROCESSING - continued

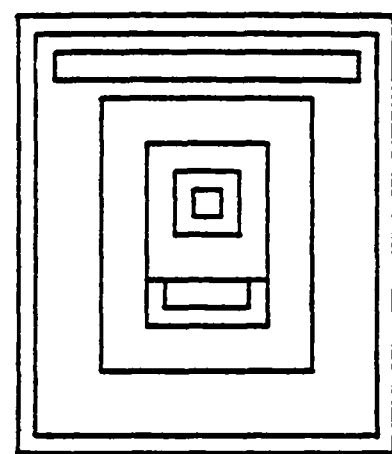
- Contact photoresist establishes apertures for ohmic contacts to the devices. (Fig. 12).
- A sample probe is performed next; device betas and breakdowns are checked.
- An E-beam evaporation of pure aluminum follows; metal thickness is 1.2μ . The layer is then delineated to form the interconnect pattern. (Fig. 3).
- A silox deposition follows; this CVD SiO_2 layer provides passivation and scratch protection. Openings to enable bonding are defined by a photoresist operation.
- A stabilization bake is next; it is followed by a detailed sample probe of device parameters and by backlap of the completed slice to a thickness of 10-12 units.



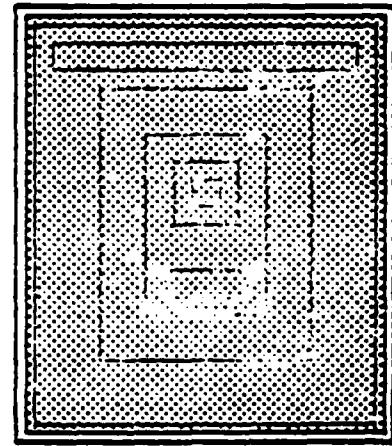
P Collector



Resistor



NPN



PNP

FIGURE 1

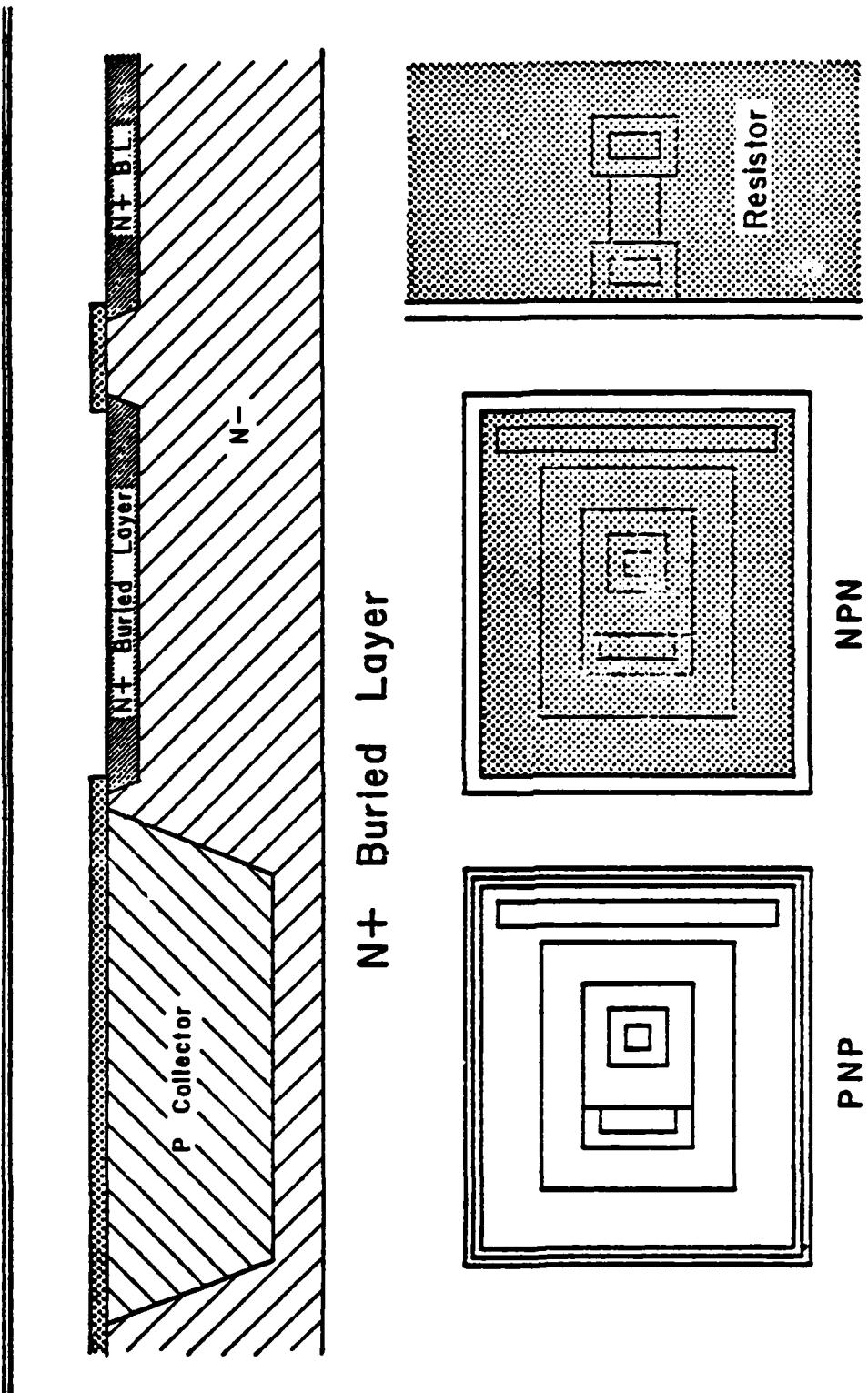


FIGURE 2

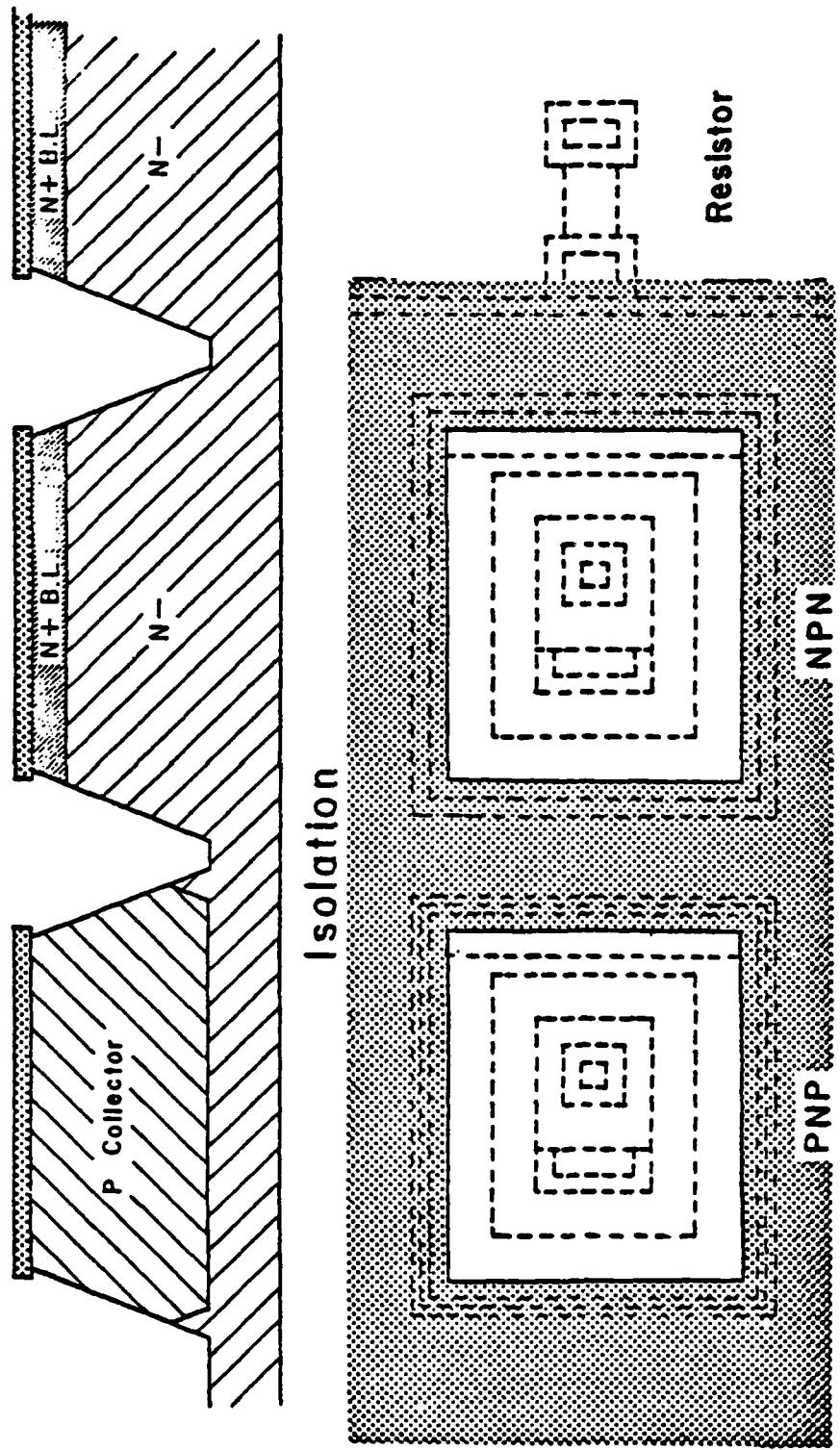
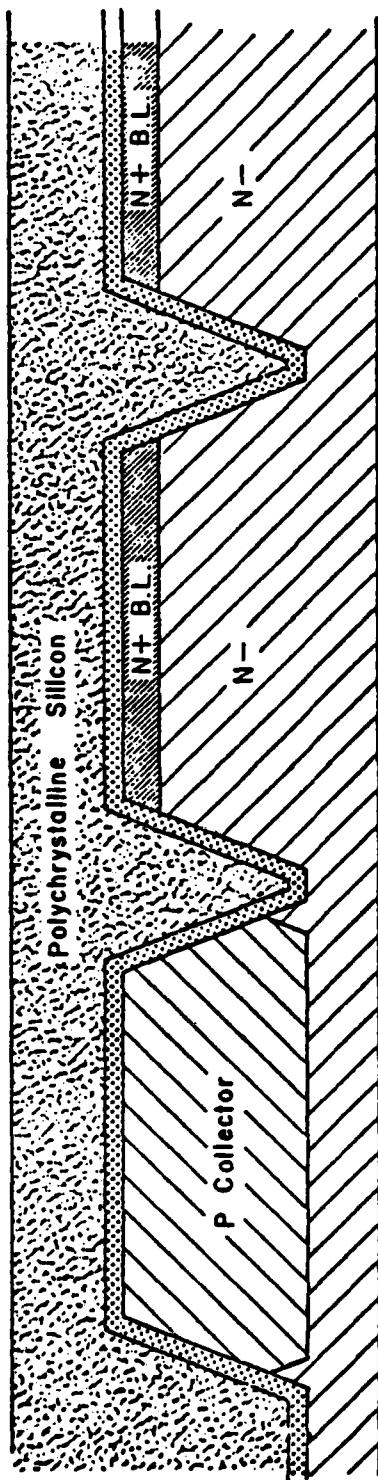
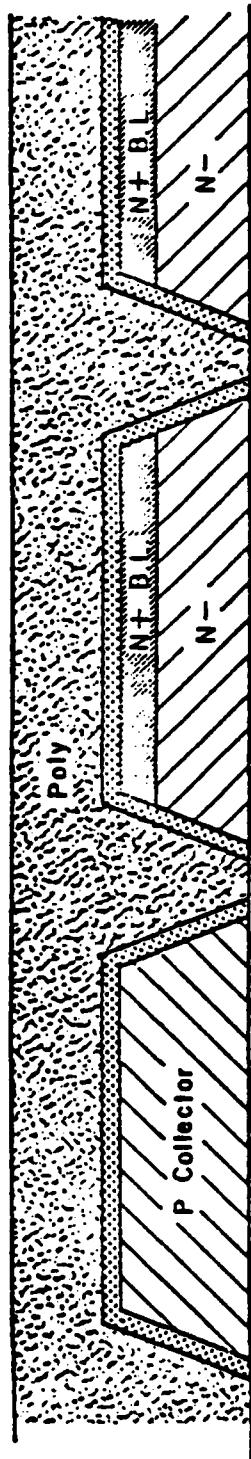


FIGURE 4

Grow Oxide in Moats, then add Poly for support.





Grind off excess material from N- side of slice.

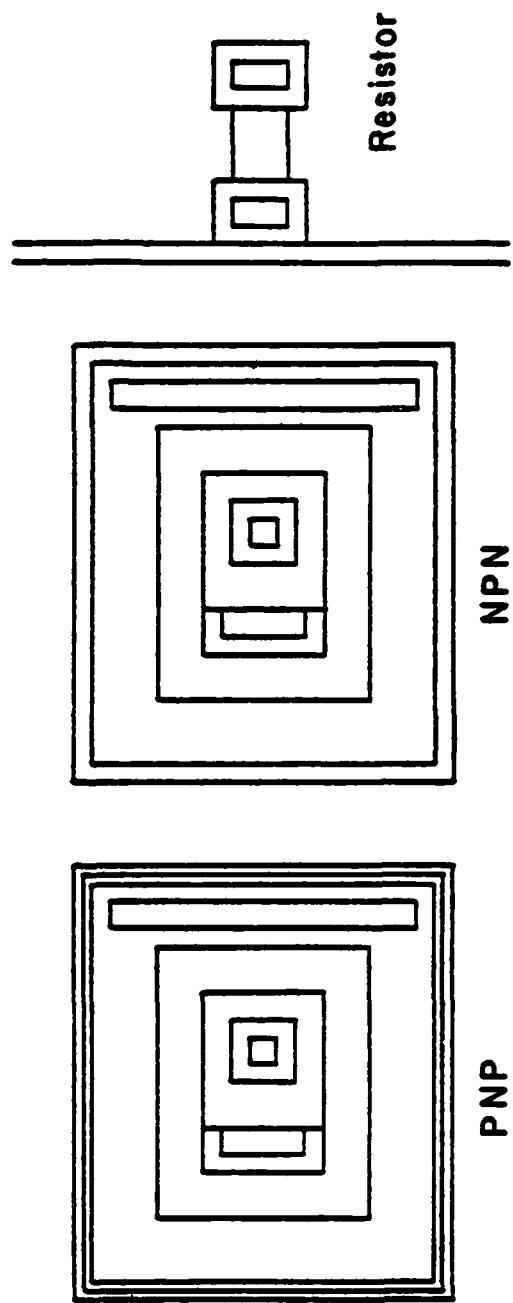


FIGURE 5

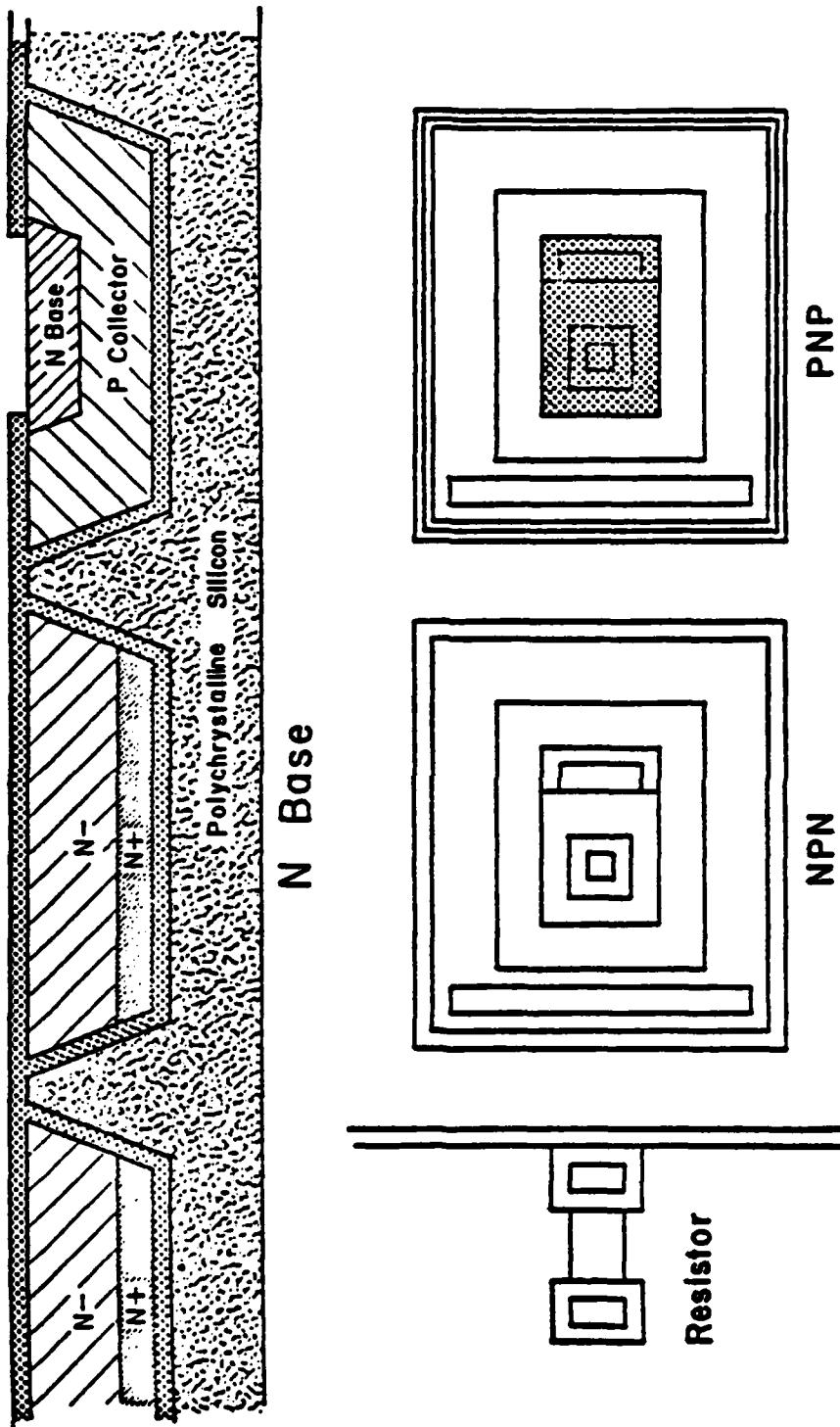


FIGURE 6

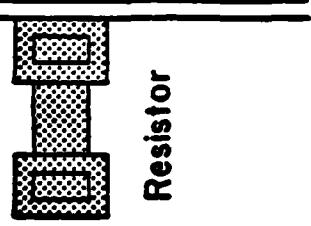
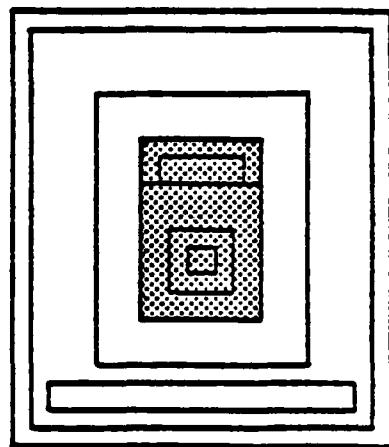
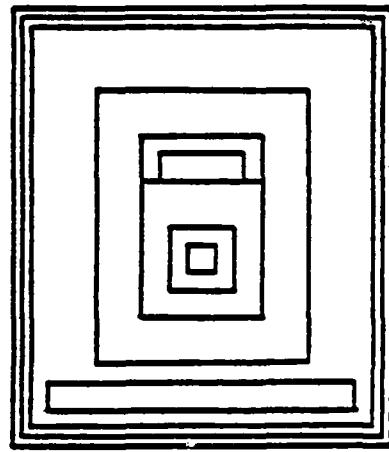
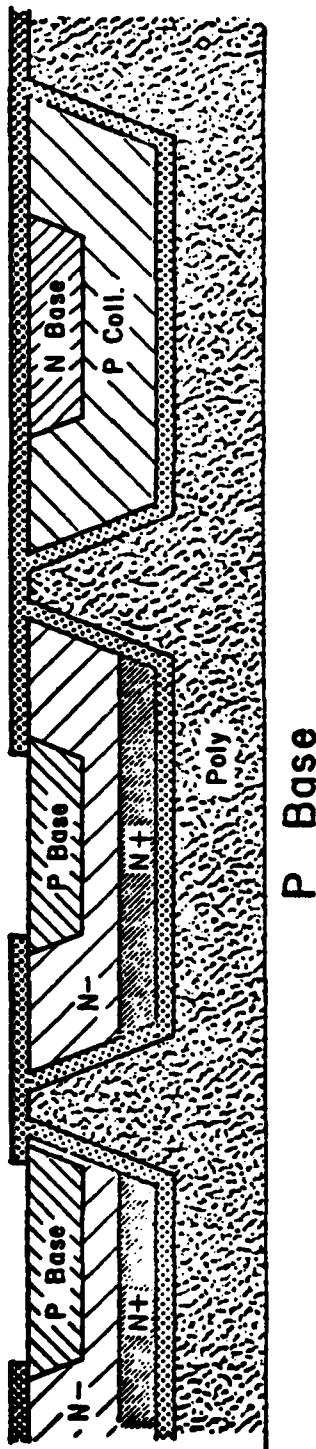
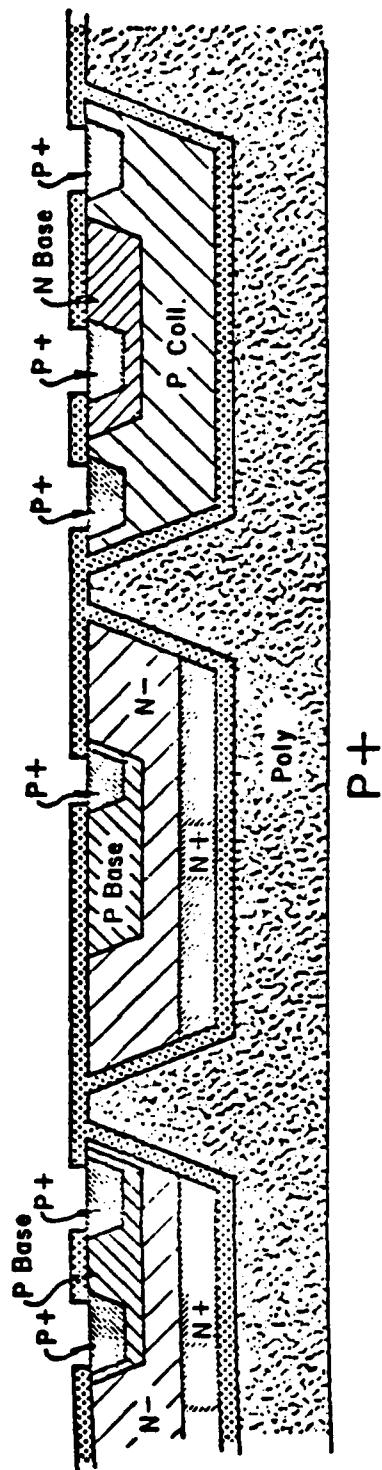
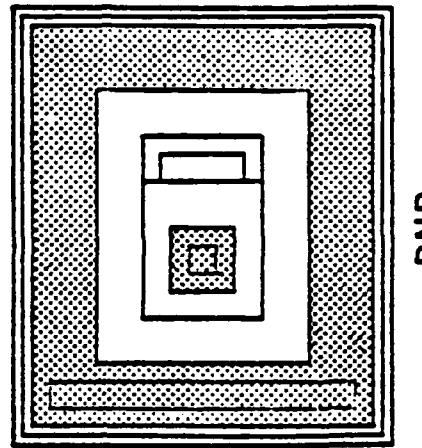


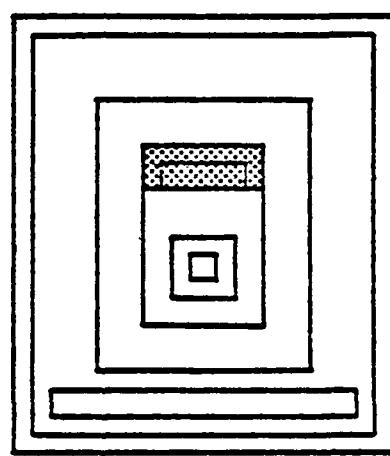
FIGURE 7



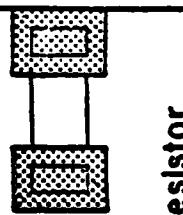
P^+



PNP



NPN



Resistor

FIGURE 8

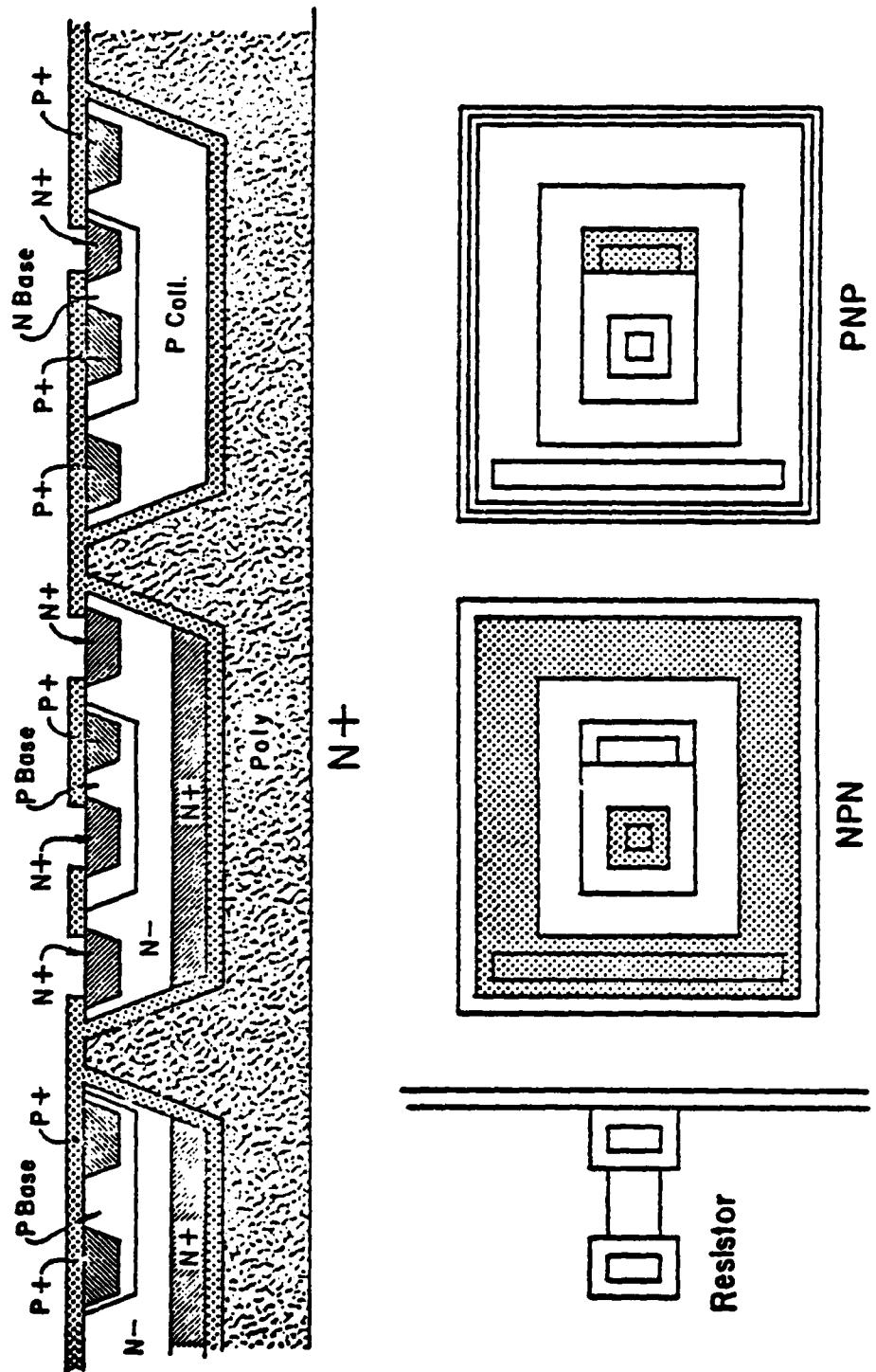
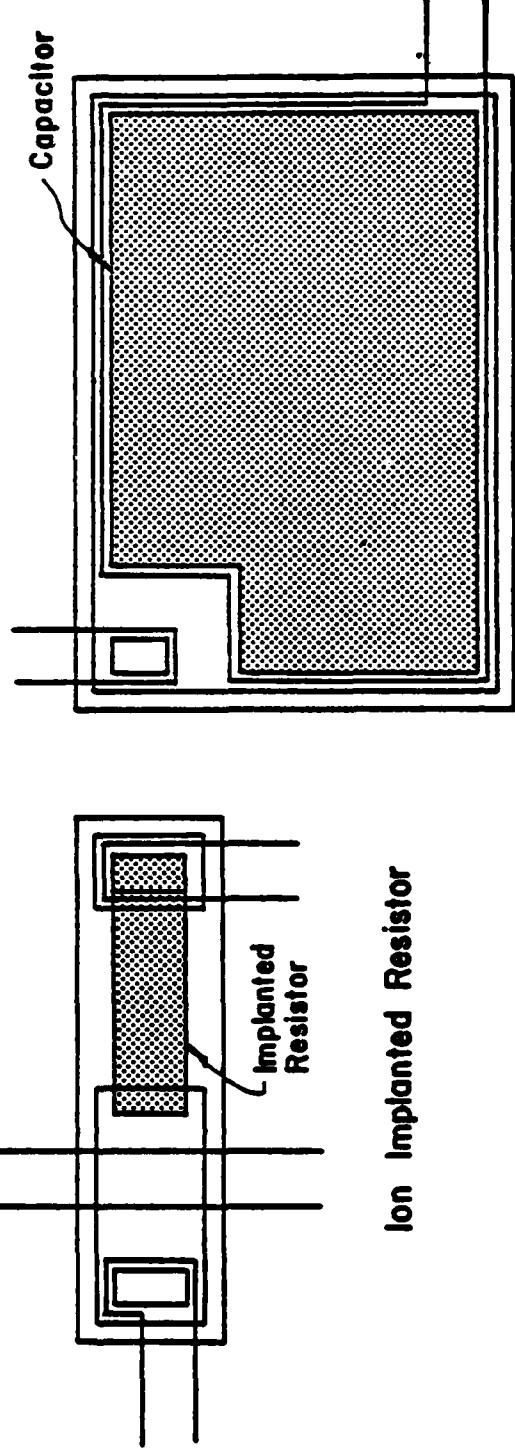
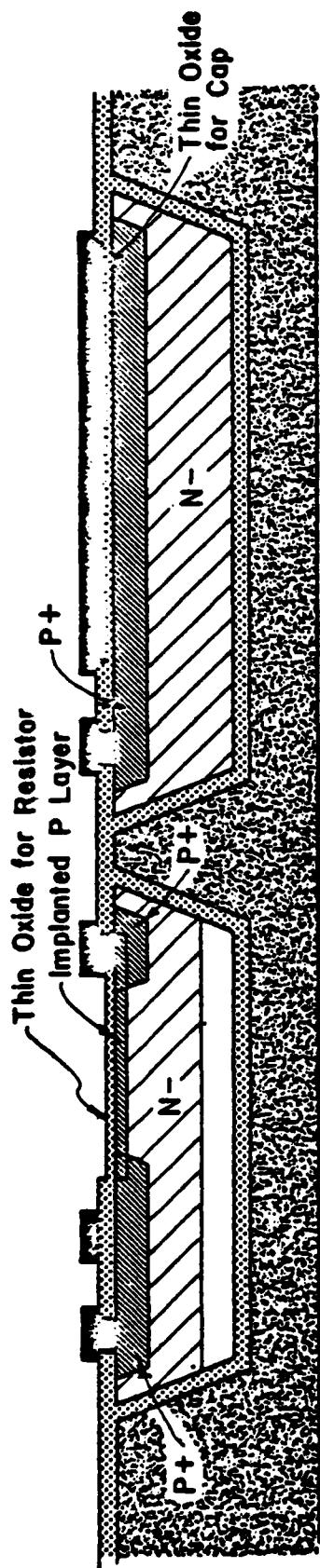


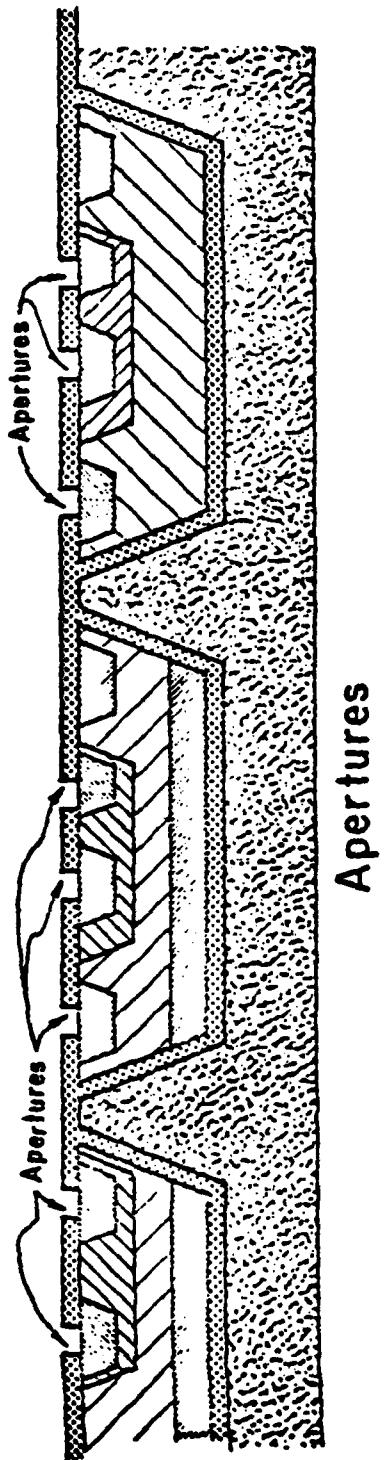
FIGURE 8



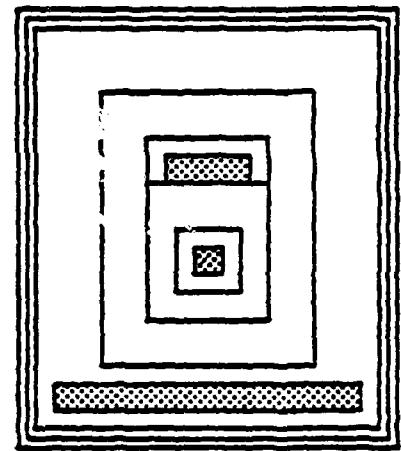
MOS Capacitor

Ion Implanted Resistor

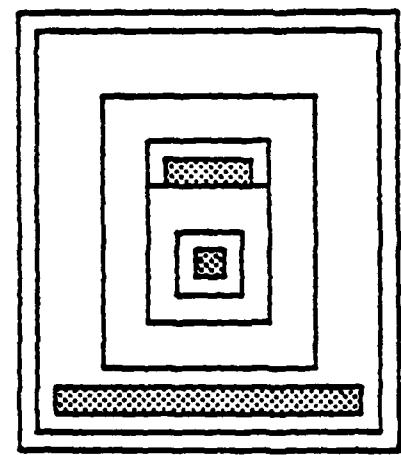
FIGURES 10 and 11



Apertures



PNP



NPN

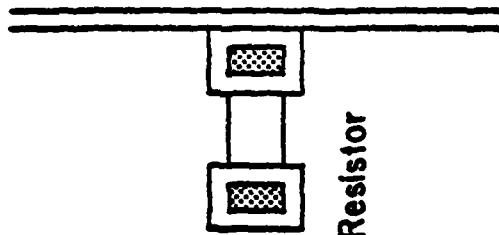
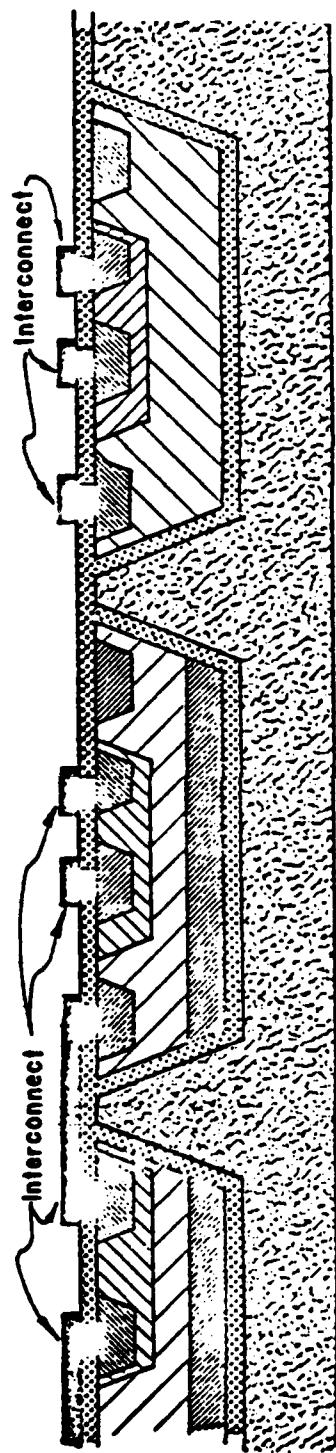


FIGURE 12



Aluminum Interconnect

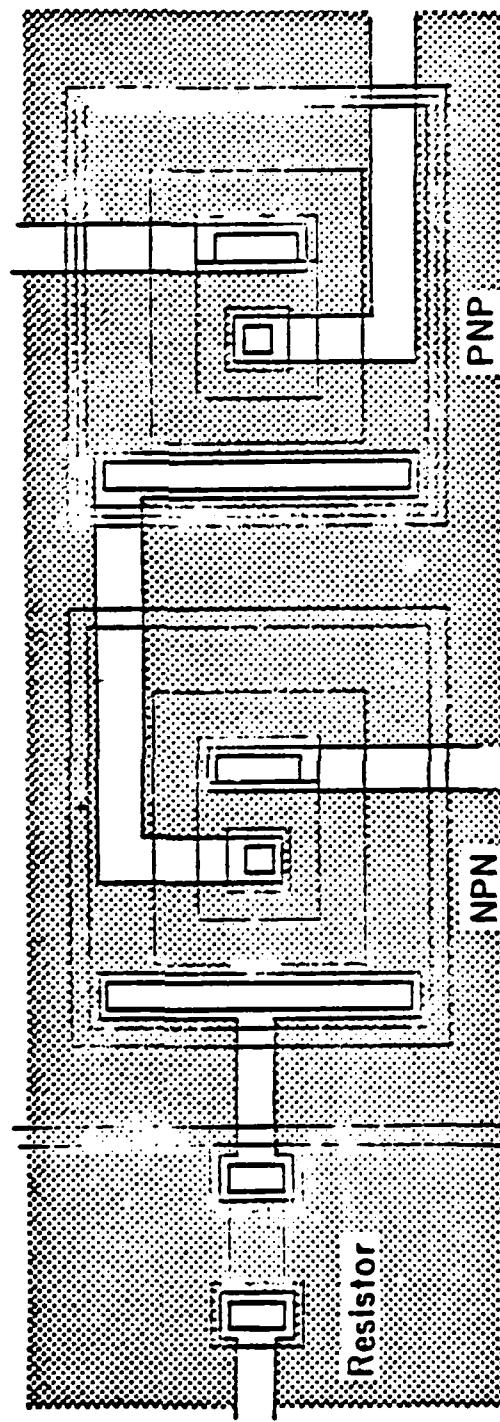


FIGURE 13

3.6 Radiation Effect Modeling

The crux of the radiation hardening effort of the DINS photopreamplifier lies in the structure of the two op amp stages. This structure resembles that of an advanced radiation hardened op amp now being developed by Harris' Programs Division. The fabrication of the preamp will be implemented by utilizing Harris' radiation hardened linear process.

Neutron and Total Dose Modeling

The primary effect of neutron and total dose radiation is a reduction in current gain and an increase in the resistivities of the lightly doped collector. At the radiation spec level of 4×10^6 rads, minimum betas of 30 and 15 can be expected for the NPN and PNP devices respectively. The collector resistance of NPN devices increases by a factor of four and by a factor of 1.5 for the PNP. All post neutron computer simulations have taken these facts into account. A complete table of Gummel-Poon model parameters, both pre and post radiation can be found in the appendix of this report. These were used for SPICE II circuit simulation of the preamplifier under these conditions.

Transient Gamma Modeling

The predominant effect of a circuit's exposure to gamma radiation is the generation of electron-hole pairs within the space-charge regions of reversed biased junctions in the circuit. This generation of carriers causes a current, I_{pp} (primary photocurrent), to flow. These photocurrents may disrupt the normal operating conditions of the circuit sufficiently to cause a spurious output signal to be produced.

By the judicious placement of compensating reverse biased junctions on critical nodes, these photocurrent effects may be minimized. Figure 4 shows how this compensation scheme is used. Also shown are the polarities of the generated currents. In computer simulations of these photocurrents, current generators of appropriate magnitude (function of island volume) are placed in parallel with all reversed biased junctions including ion-implanted resistor islands. These islands are tied off to the more positive end of the resistor and depending on the voltage drop across the resistor, up to one half of the island volume may be depleted due to the voltage gradient set up across the resistor. With the generators in place, a transient simulation will show what effects the specified level of radiation will produce.

Computer sensitivity analyses show that the photocurrents generated by the reversed biased photodiode junctions at the input are the most critical. These are applied common mode to the preamplifier however any mismatch in photodiode volume implies a mismatch in photocurrent and this mismatch appears differentially across the input. Table 1 shows percent mismatch of photodiode volume versus signal to noise ratio. Note that this is assuming a perfect match between paired photocurrents elsewhere in the system. Also shown on Table 1 are typical signal to noise ratios for nominal system conditions.

Prompt Gamma Survival

Under very large γ environments, the major concern is to prevent either aluminum interconnect fusing or secondary junction burn-out due to surge currents (assuming all devices become shorts). This is accomplished in the preamplifier design by using limiting resistors RLIM1 through RLIM9. These are N+ resistors with a pre-radiation value of 50 ohms.

The secondary concern is the part's recovery time after such an event. A worst-case computer simulation has been performed using photo-current sources generating 100 milliampere, 100 nanosecond wide pulses across every reversed biased junction in the circuit. The result of this simulation is shown in Figure 5. Under this condition, recovery time is in the order of 10 microseconds.

γ COMPUTER MODELING

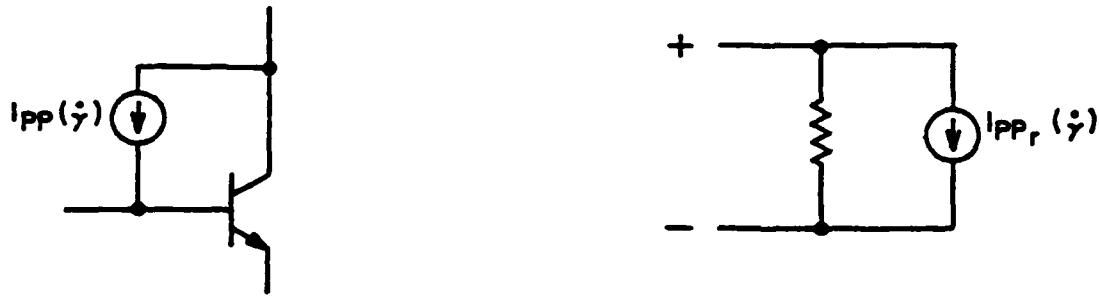
THE GAMMA RADIATION CURRENT CAN BE CALCULATED FROM THE FOLLOWING EXPRESSION:

3

$$I_{PP}(\gamma) = qg_0 \text{ Vol. } \dot{\gamma}$$

WHERE $g_0 = 4 \times 10^{13} / \text{rad-cm}^3$

COMPUTER MODELS



TYPICAL COMPENSATION SCHEME

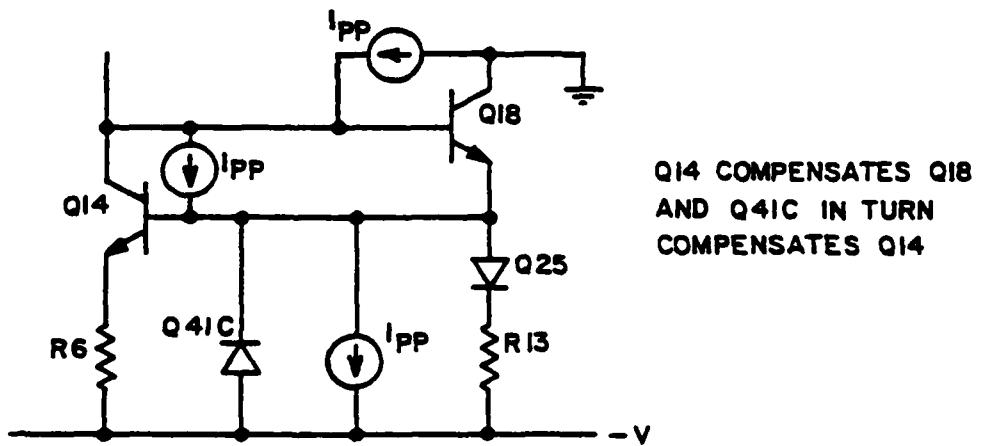


Figure 4

TABLE 1

Assumptions: - Minimum input laser signal of 300 NW and spec radiation.
 - Four megohm nominal transimpedance
 - .44 amp/watt photodiode responsivity
 - 8.25 ua photodiode photocurrent
 - All other matching is absolute

<u>Signal to Noise Ratio</u>	<u>% Mismatch in Photodiode Volume</u>
1.6 to 1	1%
.8 to 1	2%
.53 to 1	3%
.4 to 1	4%
.32 to 1	5%

Under typical system conditions of twice the worst case minimum laser signal and a gamma rate level one order of magnitude less than the specification level.

<u>Signal to Noise Ratio</u>	<u>% Mismatch in Photodiode Volume</u>
32 to 1	1%
16 to 1	2%
10.6 to 1	3%
8 to 1	4%
6.4 to 1	5%

PROMPT GAMMA RECOVERY TIME

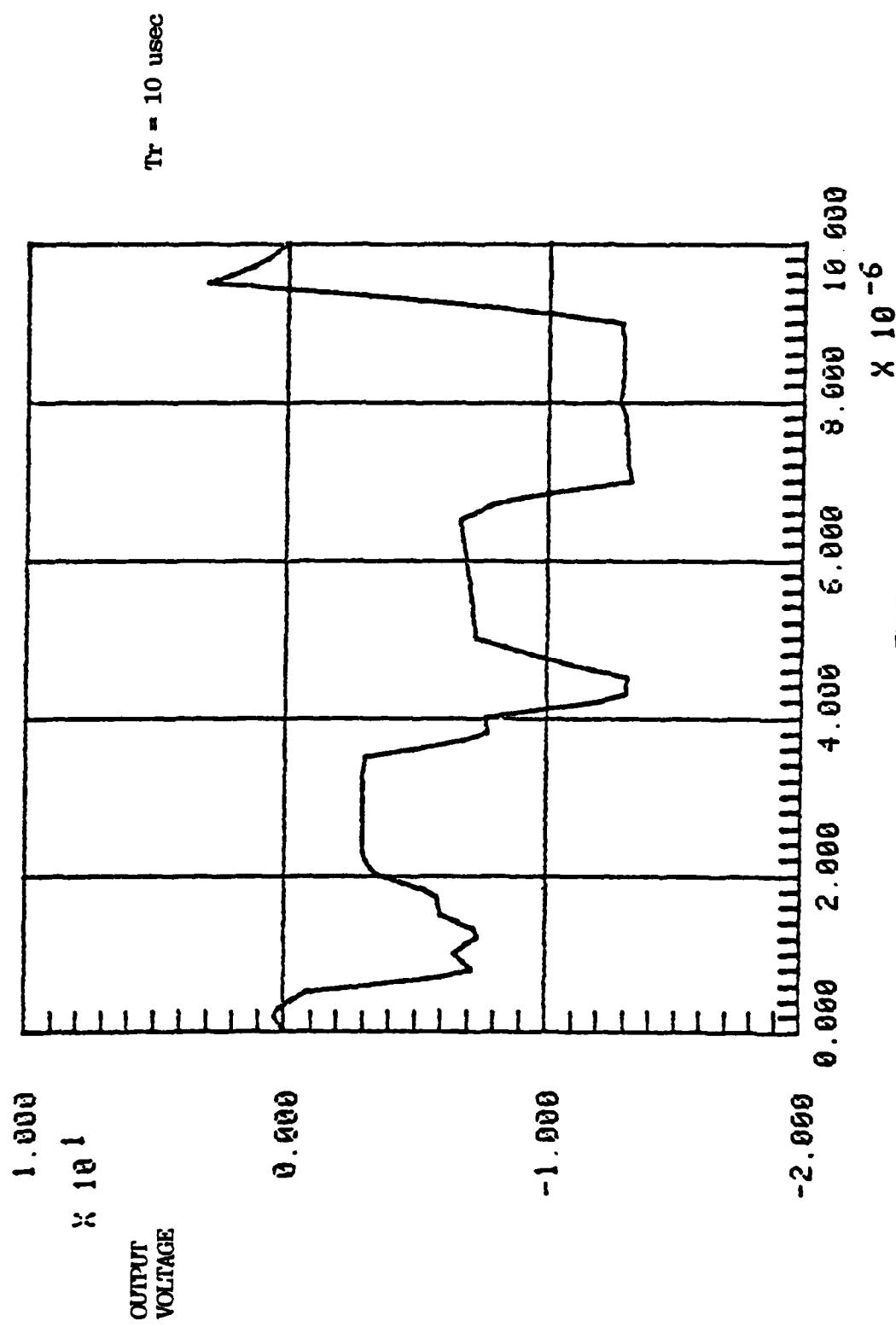
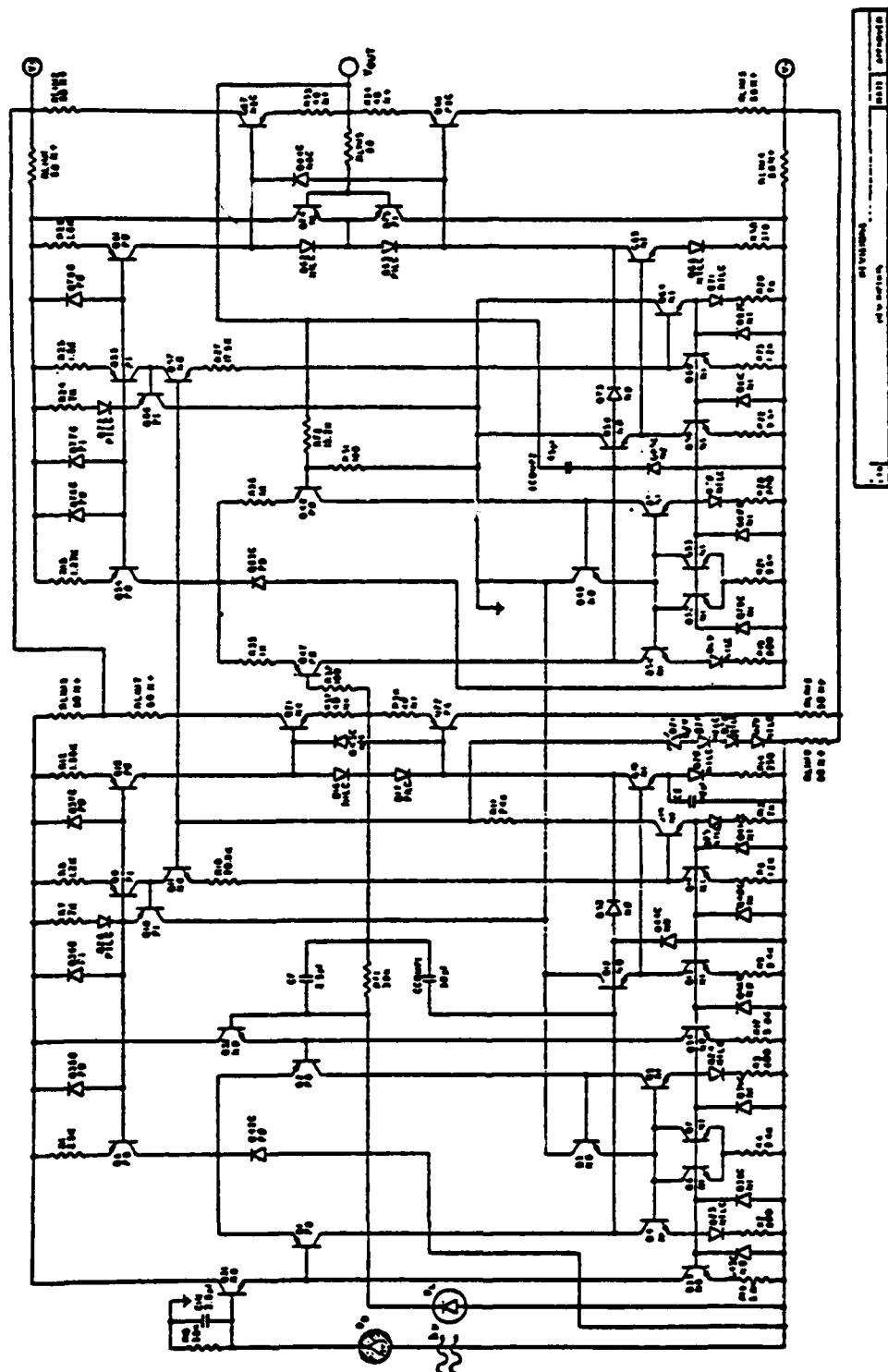


FIGURE 5

3.7 Thermal Noise Analysis

As previously stated, the noise signal generated as a result of a transient gamma event is the largest noise contributor in the system. However, for completeness a thermal noise analysis was performed over temperature to insure that these components were negligible. The simulation results showed the total output thermal noise voltage to be two orders of magnitude less than that generated by a 1% mismatch in photodiode volume. At 25°C the output noise voltage was 7 millivolts, 8.77 millivolts at 125°C and 6.5 millivolts at -55°C. Plots of output noise voltage squared versus frequency can be found in the appendix.



PHOTOAMPLIFIER SCHEMATIC

FIGURE 6

TABLE OF ELEMENT VALUES

TABLE 2

RESISTORS		NAME	VALUE	CAPACITORS		NAME	VALUE
R1						CCOMP1	5.00E-11
R2						CF	2.50E-12
R3						CE	1.00E-11
R4						CCOMP2	4.50E-13
R5						CIN	2.50E-12
R6							
R7							
R8		R3 (RF1.)					
R9		R10					
R11		R12					
R13		R14					
R15		R16					
R17		R18					
R19		R20					
R21		R22					
R23		R24					
R25		R26 (RF2.)					
R27							

4.0 CIRCUIT DESCRIPTION

4.1 General Overview

Shown in Figure 6 is the schematic diagram of the preamplifier. As mentioned earlier, the overall structure is that of two similar radiation hardened op amp stages in cascade. There are some variations between the two due to different gain-bandwidth products, stability requirements and short circuit protection requirements.

The transimpedance gain of the first stage A_1 is 30K and is set by feedback resistor RF1. Its closed loop bandwidth is set by the closed-loop pole obtained between RF1 and lead compensation capacitor CF. The bandwidth is a nominal value of 2 megahertz. Elements R15 and C1N are used to match the impedance seen at both input ports. This is important in order to minimize current induced voltage offset and also to balance the photocurrents generated at the input by these resistors. The open loop bandwidth of A_1 is set by CCOMP1 and the gm of the input stage, using the classical dominant pole approach. It is a nominal value of 8 megahertz. Only 2 megahertz was required for the gain-bandwidth product of A_1 (voltage gain is unity in this stage) however any further reduction would require a larger value CCOMP1. At its present value, the phase margin of the stage is greater than 45°. The value of CCOMP1 is 50 pf (relatively large). Any further lowering of gm will increase the amplifier's photocurrent sensitivity due to the reduction in operating current in the input differential pair.

Figure 6 also shows the input photodiode D_L , and the compensating masked photodiode D_P . D_P is required to provide matched (common-mode) photocurrents to the preamplifier during a transient gamma event. D_P also assures a match in impedances seen by both input terminals. During circuit simulations both photodiodes were modelled as capacitors whose value was the sum of the diode's depletion and isolation capacitances. A worst case figure of 6 pf was used.

The second stage A_2 is a non-inverting amplifier in a gain of 133. The closed loop voltage gain is set by

$$\frac{RF2 + R31}{R31}$$

Resistor R32 matches the impedances seen by both input ports of A_2 . This resistor shall be a P+ resistor thereby generating very low radiation currents.

There are four ion-implanted resistors in the circuit whose islands shall not be tied off to the more positive side of the resistor. These are R15, RF1, RF2 and R31. Depending on the offset condition of A_1 and A_2 , these resistors may have voltages of either polarity across them. If they were tied off one could establish a forward biased junction between the P implant and the N - island.

Resistors R15 and RF1 shall be broken up into ten series connected 3K resistors in separate islands to limit the photocurrent contribution they generate to that of a single 3K resistor.

RF2, RF3, RF4 MAPS AT POINTS OF TIME

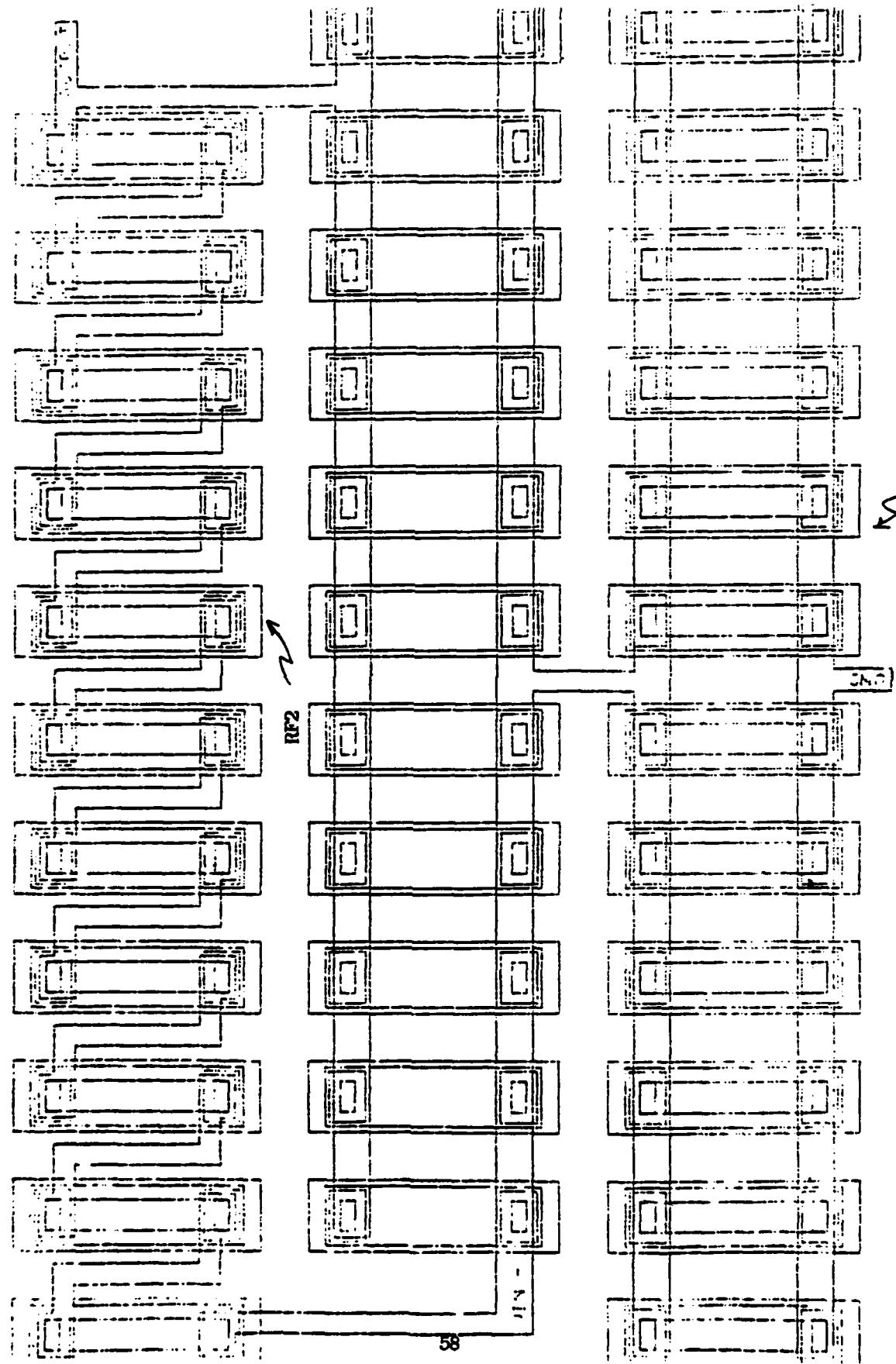


FIGURE 7

TABLE 3
ELECTRICAL PERFORMANCE

<u>GBW</u>	<u>REQUIRED</u>	<u>ACTUAL</u>
A_1	2 mHz	8 mHz
A_2	266 mHz	276 mHz

<u>ACTUAL</u> <u>POWER DISSIPATION (Two Channels)</u>	<u>TEMPERATURE</u>
212 Milliwatts	25°C
220 "	125°C
208 "	-55°C

AC STEADY-STATE OUTPUT VOLTAGE
(Assuming no offsets)

PRE-RAD V_{out} (SS AC) = 526 Millivolts

POST-RAD V_{out} (SS AC) = 519 Millivolts
(Neutron Spec)

These outputs were obtained based on a minimum 300 nanowatt laser signal and a photodiode responsivity of .44 amps/watt. The corresponding steady state AC input signal used was 132 nanoamperes.

The case of resistors RF2 and R31 is more complex. These two resistors have significantly different values (RF2 = 13.2K and R31 = 100 ohms) however since they set the gain of A₂ they must ratio. In addition, their photocurrent generation must be mutually compensating in order that no differential voltage appears at A₂'s input. The approach that was chosen dictated RF2 to be built as eleven 1.2K series connected resistors in separate islands and R31 to be twelve 1.2K parallel connected resistors in separate islands. This resolves the ratio tracking problem but leaves R31 generating twelve times the photocurrent of RF2. This was resolved by paralleling eleven dummy islands, whose volume matches that of a 1.2K resistor, with RF2. A summary of this compensation scheme is shown in Figure 7.

A gain of 133 for A₂ implies this stage must have a gain-bandwidth product of greater than 250 megahertz. This figure would be unreasonable if the amplifier were required to be stable at a closed loop gain of unity. However at a gain of 133, greater than 45 degrees of phase margin has been achieved. Emitter degeneration resistors R35 and R36 tend to reduce the gm of the input stage. However they are required to aid in the stability of A₁. The gm of A₂'s input stage is

$$gm = \frac{1}{R35 + 2 \frac{KT}{q \cdot I \cdot Q47}}$$

The collector current of Q47 is 185 microamps and therefore gm is 780 microhms. Gain-bandwidth product is defined as

$$GBW = \frac{gm}{2\pi C}$$

Here C is element OCOMP2 or .45 pf therefore the gain-bandwidth product of A₂ is 276 megahertz.

When reading the system schematic, all device names with a trailing C in the name are photocurrent compensation devices and are reverse biased.

TABLE 3 lists gain-bandwidth requirements, actual total power dissipation and actual pre and post radiation steady-state output voltages.

4.2 Biasing

Both stages A₁ and A₂ are biased from a common voltage reference consisting of D21, Q27, Q28 and Q29 however each stage maintains its own isolated NPN and PNP base biasing rails. R24 sets up current of 275 ua to bias the zener QN. Devices Q11 and Q57 then set up reference currents for the four independent base rails located at the bases of Q9, Q14, Q55 and Q60.

4.3 Input Stages

The inputs stages of A₁ and A₂ differ in structure. For A₁ an NPN/PNP modified Darlington configuration was chosen (Q31-Q1 and Q32-Q2). The necessity for this type of configuration here is due to post-neutron bandwidth reduction due to a lowering of gm. The expression for gm of a differential pair is

$$gm = \frac{1}{2} \left[\frac{r_b + r_s + r_e}{s_n} \right]$$

Where r_b is the base spreading resistance, r_e is the dynamic input impedance and R_s is a source impedance. For a radiation insensitive gm it is desirable that the second term be dominant since it is not beta dependent. If a simple differential pair were used, R_s would actually be R15 or RF1 (30K). Therefore under post radiation conditions, betas would not be large enough to adequately swamp out this term. Using the Darlington approach, the gm expression is

$$gm = \frac{1}{2} \left[\frac{r_{b1} + R_s + r_{b31}}{\frac{\beta_p}{\beta_n} + r_{e1}} \right]$$

and the R_s term now is effectively buffered.

The input stage of A_2 sees a low source impedance. At the non-inverting input this consists of R32 in series with the output of A_1 and approximately R31 in parallel with RF2 at the inverting input. Therefore a simple differential pair was chosen. Upon initial simulation of the open loop gain of A_1 a 10 DB gain peak was detected around 50 megahertz. The peak was caused by the fact that at 50 megahertz the feedback factor of A_2 was low enough that A_2 's input impedance began to look capacitive. At the same time, at high frequencies, the impedance looking into the emitter of a follower stage emulates an inductor. This creates a now well known tank circuit effect. Two changes were the key to the removal of the peak to obtain the smooth roll-off characteristics presently seen. First, emitter degeneration resistors R35 and R36 were used to increase the real part of A_2 's input impedance. Second, capacitor CE in A_1 in parallel with the dynamic impedance of Q20 plus R14 generates a zero in the transfer function. The combined effect of these two elements assures the stability of A_1 with a simulated phase margin of 65 degrees.

4.4 Active Loads and Gain Stages .

The input stage current mirrors used in A_1 and A_2 are modifications of the classic Widlar current mirror. In A_1 devices Q3-Q4-Q5-Q6 and Q7 form the mirror. Q5 is essentially diode connected by the base-emitter junction of Q3. The parallel combination of Q6-Q7 draw out Q3's emitter current from the base rail of the mirror. Note that devices Q6 and Q7 have the same areas as Q4 and Q5 and therefore serve as photocompensation devices. Device Q12 serves as a buffer between the mirror and the gain stage Q19. Q12 is biased at the same current as Q3 so the base currents they rob from the collectors of Q4-Q5 are equal.

Q12 and Q19 form the gain stage of A_1 . Capacitor CCOMP1 performs the pole-splitting action of the integrator. Note that this capacitor ties to the output of A_1 and not to the collector of Q19. Simulations show a greater degree of phase margin is achievable using this approach.

4.5 Output Stage and Short Circuit Protection

Both A_1 and A_2 use the standard class AB output stage found on most op amps used today. The output stage of A_2 differs from that of A_1 in operating current and device size. Also, A_2 incorporates a short circuit protection scheme using Q74 and Q75. Since system specifications required A_2 to drive a

coaxial cable, a parallel RC load was used throughout the simulations. The value of R was 2K and C was 100 pf. The large output devices and operating points help source and sink the larger currents necessary to drive such a load.

Under short circuit conditions, large currents may initially flow through resistors R33 or R34 (depending on the direction of the short). If the drop across R33 reaches one diode drop, device Q75 turns on and robs driving current from the gain stage. A similar condition of opposite polarity causes a similar effect from R34 and Q74.

4.6 Breadboard Simulation Results

Shown in Figure 7 is the block diagram of the breadboard version of the photopreamplifier. For the transimpedance stage, the afore mentioned radiation hardened op amp (913) was used. This part is internally compensated and has a gain bandwidth product of 10 megahertz. For this reason it was not feasible to use this op amp for the second stage since in the breadboard version this stage requires a gain bandwidth product of 100 megahertz (BW = 1 mHz at a gain of 100). Instead, a commercial op amp, the HA5190 manufactured by Harris' Products Division was used. This part has a gain bandwidth product of 150 megahertz but is not radiation hardened.

The purpose of constructing the printed-circuit board version of the system was to see if the required overall transimpedance of 3 megohms and a 1 megahertz bandwidth could be achieved without instability. Also the circuit was to be used to amplify signals from prototype photodiodes whose fabrication was near completion. The results achieved were very good. A spectrum analyser showed the gain at 3.1 megohms and a bandwidth of 1.5 megahertz. The laser light used to drive the photodiodes was modulated by a 100 kilohertz square wave using a quartz modulator and the diodes output was properly amplified by the breadboard preamplifier.

DINS PHOTOPREAMP BREADBOARD

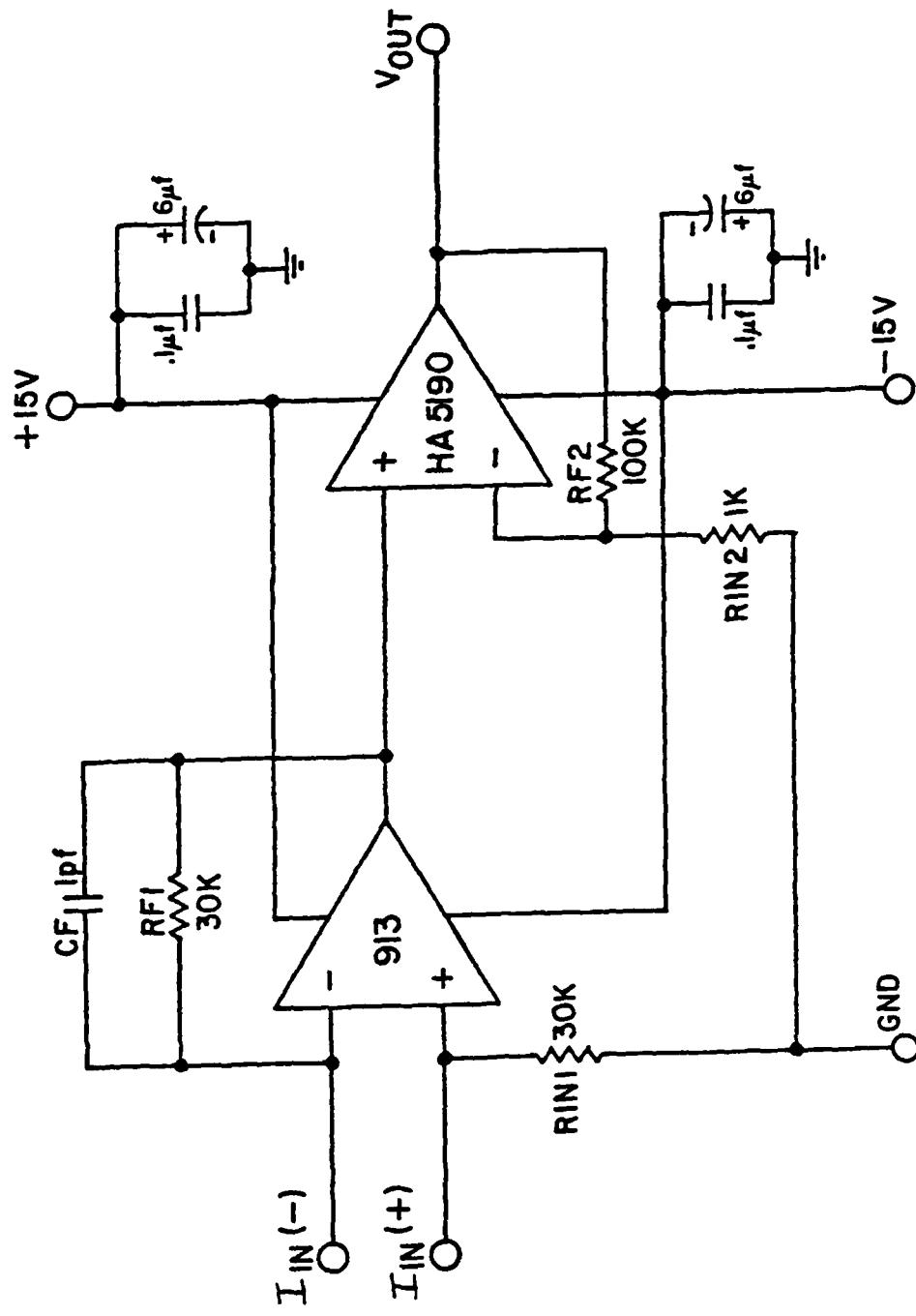


Figure 8

5.0 Conclusion

A design approach and a method of implementation has been presented. Computer circuit simulations have verified that the DINS photodetector will meet gain and bandwidth specifications over temperature and process variation. In addition the part will be able to meet these requirements after exposure to neutron fluence of the spec level. Simulations also show the preamplifier's ability to drive a capacitive load without instability and its indefinite tolerance to an output short circuit. The photodetector is also hardened to withstand a transient gamma event of the specified level. This is the single most critical spec of the system and is also the most difficult to achieve. As can be seen from Table 1, only 1% match in photodiode volume will provide a signal to noise ratio greater than 1 to 1. Statistical data (from a different process) shows 5% matching to be an achievable tolerance, however, at this level the signal to noise ratio is short of spec by a factor of three. It was stated during the status meeting held on June 7th that a γ level of one order of magnitude less than spec would be representative of what the photodetector would experience. Under this condition, a 5% mismatch in photodiode volume implies a signal to noise ratio of 3.2 to 1 or a factor of three greater than spec. We feel that this level of γ is a more realistic figure to expect the photodetector to tolerate.

The design presented here has been the combined effort of many individuals whose skills range from computer-aided design to state of the art process enhancement. It is our belief that provided the above compromise in spec is assured, the DINS photodetector effort holds a great chance for success.

APPENDIX 1.0

MODEL PARAMETERS

- 1.1 PRE-RADIATION PARAMETERS
- 1.2 POST NEUTRON PARAMETERS

PRE-RADIATION GUMMEL-POON MODEL PARAMETERS FOR SPICE 11 CIRCUIT
SIMULATION OF THE D11S PHOTOPREAMPLIFIER (TEMPERATURE 25 DEGREES C)

----- BJT MODELS -----

NAME	TYPE	BR = 9.000E+00	RE = 0.000E+00	C2 = 6.000E+02	NC = 1.450E+00	CJE = 8.200E-13	PC = 4.700E-01	IS = 1.000E-15	UA = 7.500E+01	NE = 2.000E+00	TF = 1.400E-10	PE = 8.400E-01	MC = 2.100E-01	RB = 3.200E+02	UB = 2.000E+01	IKR = 1.000E-02	TR = 7.500E-08	ME = 3.700E-01	EG = 1.110E+00
RN1LC	NPN	BR = 9.000E+00	RE = 0.000E+00	C2 = 6.000E+02	NC = 1.450E+00	CJE = 8.200E-13	PC = 4.700E-01	IS = 7.000E-16	UA = 6.000E+01	NE = 2.000E+00	TF = 3.500E-10	PE = 6.300E-01	MC = 3.300E-01	RB = 2.500E+02	UB = 2.000E+01	IKR = 1.000E-02	TR = 4.000E-07	ME = 2.600E-01	EG = 1.110E+00
RPI1LC	PNP	BR = 9.000E+00	RE = 0.000E+00	C2 = 6.000E+02	NC = 1.450E+00	CJE = 9.500E-13	PC = 3.500E-01	IS = 7.000E-16	UA = 6.000E+01	NE = 2.000E+00	TF = 3.500E-10	PE = 6.300E-01	MC = 3.300E-01	RB = 2.500E+02	UB = 2.000E+01	IKR = 1.000E-02	TR = 4.000E-07	ME = 2.600E-01	EG = 1.110E+00
RN0	NPN	BR = 9.000E+00	RE = 0.000E+00	C2 = 6.000E+02	NC = 1.450E+00	CJE = 4.500E-13	PC = 4.700E-01	IS = 5.000E-16	UA = 7.500E+01	NE = 2.000E+00	TF = 1.400E-10	PE = 8.400E-01	MC = 2.100E-01	RB = 3.890E+02	UB = 2.000E+01	IKR = 5.000E-03	TR = 7.500E-08	ME = 3.700E-01	EG = 1.110E+00

RN1	NPN BF = 2.000E+02 RC = 6.000E+02 IK = 5.00E-02 C4 = 4.00E+02 CS = 5.00E-13 CJC = 0.00E+00	BR = 9.000E+00 RE = 9.000E+02 C2 = 4.50E+00 NC = 2.00E-13 CJE = 4.00E-01 PC = 7.00E-01	IS = 1.000E+15 UA = 7.000E+00 NE = 1.400E-10 TF = 8.400E-01 PE = 2.100E-01 MC =	RB = 3.200E+02 UB = 1.000E-02 IKR = 7.500E-08 TR = 3.700E-01 ME = 1.10E+00 EG =	RB = 1.530E+02 UB = 2.000E+01 IKR = 4.7500E-08 TR = 3.700E-01 ME = 1.10E+00 EG =	RB = 3.000E+02 UB = 2.000E+01 IKR = 4.7500E-08 TR = 3.700E-01 ME = 1.10E+00 EG =
RN4	NPN BF = 2.000E+02 RC = 1.750E+02 IK = 5.00E-01 C4 = 4.00E+02 CS = 4.00E-12 CJC = 0.00E+00	BR = 9.000E+00 RE = 9.000E+02 C2 = 4.50E+00 NC = 1.200E-12 CJE = 4.00E-01 PC =	IS = 1.000E+15 UA = 7.000E+00 NE = 1.400E-10 TF = 8.400E-01 PE = 2.100E-01 MC =	RB = 9.000E+01 UB = 2.000E+01 IKR = 4.7500E-08 TR = 3.700E-01 ME = 1.10E+00 EG =	RB = 9.000E+01 UB = 2.000E+01 IKR = 4.7500E-08 TR = 3.700E-01 ME = 1.10E+00 EG =	RB = 9.000E+01 UB = 2.000E+01 IKR = 4.7500E-08 TR = 3.700E-01 ME = 1.10E+00 EG =
RN8C	NPN BF = 2.000E+02 RC = 8.000E+01 IK = 4.000E-01 C4 = 4.500E+02 CS = 2.00E-12 CJC = 0.00E+00	BR = 9.000E+00 RE = 9.000E+02 C2 = 4.500E+00 NC = 1.450E+00 CJE = 6.200E-12 PC = 4.700E-01	IS = 8.000E+15 UA = 7.500E+01 NE = 2.000E+00 TF = 1.400E-10 PE = 8.400E-01 MC =	RB = 9.000E+00 UB = 2.000E+01 IKR = 4.7500E-08 TR = 3.700E-01 ME = 1.10E+00 EG =	RB = 9.000E+00 UB = 2.000E+01 IKR = 4.7500E-08 TR = 3.700E-01 ME = 1.10E+00 EG =	RB = 9.000E+00 UB = 2.000E+01 IKR = 4.7500E-08 TR = 3.700E-01 ME = 1.10E+00 EG =
RP0	PHP BF = 1.500E+02 RC = 1.428E+02 IK = 5.00E-02 C4 = 4.520E+02 CS = 2.000E-13 CJC = 6.000E-01	BR = 9.000E+00 RE = 9.000E+02 C2 = 6.000E+00 NC = 1.450E+00 CJE = 1.5200E-13 PC = 3.500E-01	IS = 5.00E-16 UA = 5.000E+00 NE = 3.500E-10 TF = 6.900E-01 PE = 3.300E-01 MC =	RB = 3.000E+02 UB = 2.000E+01 IKR = 4.7500E-07 TR = 3.600E-01 ME = 1.10E+00 EG =	RB = 3.000E+02 UB = 2.000E+01 IKR = 4.7500E-07 TR = 3.600E-01 ME = 1.10E+00 EG =	RB = 3.000E+02 UB = 2.000E+01 IKR = 4.7500E-07 TR = 3.600E-01 ME = 1.10E+00 EG =

RP1	PNP	BR = 9.000E+00	RB = 2.500E+02
	BF = 1.500E+02	RE = 6.000E+00	UB = 2.000E+01
	RC = 1.040E+03	C2 = 6.000E+02	IKR = 1.000E-02
	IK = 1.500E+02	NC = 1.450E+00	TR = 4.000E-07
	C4 = 1.520E+02	CJE = 1.500E-12	ME = 2.600E-01
	CCS = 2.500E-13	PC = 3.500E-01	EG = 1.110E+00
	CJC = 8.600E-13		
RP4	PNP	BR = 9.000E+00	RB = 7.500E+01
	BF = 1.500E+02	RE = 6.000E+00	UB = 2.000E+01
	RC = 1.000E+02	C2 = 6.000E+02	IKR = 4.000E-02
	IK = 1.000E+01	NC = 1.450E+00	TR = 4.000E-07
	C4 = 4.520E+02	CJE = 3.700E-12	ME = 2.600E-01
	CCS = 4.400E-13	PC = 3.500E-01	EG = 1.110E+00
	CJC = 2.500E-12		
RP8C	PNP	BR = 9.000E+00	RB = 3.700E+01
	BF = 1.500E+02	RE = 6.000E+00	UB = 2.000E+01
	RC = 1.160E+02	C2 = 6.000E+02	IKR = 6.000E-02
	IK = 1.000E+01	NC = 1.450E+00	TR = 4.000E-07
	C4 = 4.520E+02	CJE = 7.300E-12	ME = 2.600E-01
	CCS = 1.200E-12	PC = 3.500E-01	EG = 1.110E+00
	CJC = 4.000E-12		

----- ZENER DIODE MODEL -----

DZR	RS = 7.500E+01	TT = 1.400E-10
I _S = 5.000E-16	PB = 8.400E-01	EQ = 1.110E+00
C _{JO} = 4.500E-13	KF = 9.000E+00	FC = 5.000E-01
P _T = 3.000E+00	I _{BU} = 5.000E-04	
B _U = 6.200E+00		

(TEMPERATURE 125 DEGREES C)

----- BJT MODELS -----

NAME	TYPE	BR =	RE =	C2 =	NC =	CJE =	PC =	BR =	RE =	C2 =	NC =	CJE =	PC =	BR =	RE =	C2 =	NC =	CJE =	PC =	BR =	RE =	C2 =	NC =	CJE =	PC =	BR =	RE =	C2 =	NC =	CJE =	PC =
RH1LC	NPN	1.224E+01	0.900E+00	1.739E+00	1.450E+00	2.000E-13	2.700E-01	1.125E-10	0.900E+01	1.739E+00	1.450E+00	2.000E-13	2.700E-01	3.840E+02	2.000E+01	1.000E-02	1.150E-07	3.700E-01	1.10E+00	3.668E+02	2.000E+01	1.000E-02	1.150E-07	3.700E-01	1.10E+00						
BF =	5.000E+02							1.000E+03						1.000E+01						1.000E+01						1.000E+01					
RC =	8.030E+02							1.000E+00																							
IK =	5.000E-02							1.000E-10																							
C4 =	4.101E+01							1.000E-01																							
CCS =	4.500E-13							2.000E-13																							
CJC =	8.000E-13							2.700E-01																							
RPILC	PNP	1.052E+01	0.900E+00	1.739E+00	1.450E+00	2.000E-13	2.700E-01	1.123E-11	0.900E+01	1.739E+00	1.450E+00	2.000E-13	2.700E-01	3.000E+02	2.000E+01	1.000E-02	1.150E-07	3.700E-01	1.10E+00	4.668E+02	2.000E+01	1.000E-02	1.150E-07	3.700E-01	1.10E+00						
BF =	1.950E+02							1.000E+03						1.000E+01						1.000E+01						1.000E+01					
RC =	1.000E+03							1.000E-02																							
IK =	5.000E-02							1.000E+01																							
C4 =	4.101E+01							1.000E-01																							
CCS =	4.500E-13							2.000E-13																							
CJC =	8.000E-13							2.700E-01																							
RH0	NPH	1.224E+01	0.900E+00	1.739E+00	1.450E+00	2.000E-13	2.700E-01	1.124E-11	0.900E+01	1.739E+00	1.450E+00	2.000E-13	2.700E-01	5.624E-11	7.500E+01	1.000E+01	1.000E-02	1.150E-07	3.700E-01	1.10E+00	4.668E+02	2.000E+01	1.000E-02	1.150E-07	3.700E-01	1.10E+00					
BF =	2.500E+02							2.106E+02																							
RC =	2.500E+02							2.500E-02																							
IK =	2.500E-02							4.101E+01																							
C4 =	4.101E+01							2.000E-13																							
CCS =	2.000E-13							5.400E-13																							
CJC =	5.400E-13							1.10E+00																							

RF1	NPN	BF = 2.500E+02 RC = 3.500E+02 IK = 4.00E-01 C4 = 8.00E-13 CCS = 2.300E-12 CJC = 2.00E-13	BR = 1.224E+01 RE = 0.00E+00 C2 = 1.450E+00 NC = 1.92E-13 CJE = 2.700E-01 PC = 4.00E+01	IS = 1.125E-10 VA = 7.500E+01 NE = 2.00E+00 TF = 1.400E-10 PE = 5.400E-01 MC = 2.100E-01	RB = 3.840E+02 UB = 2.000E+01 IKR = 1.000E-02 TR = 1.150E-07 ME = 3.700E-01 EG = 1.100E+00
RN4	NPN	BF = 2.500E+02 RC = 3.500E+02 IK = 4.00E-01 C4 = 4.101E+01 CCS = 4.400E-13 CJC = 2.300E-12	BR = 1.224E+01 RE = 0.00E+00 C2 = 1.789E+00 NC = 1.450E+00 CJE = 2.00E-12 PC = 2.700E-01	IS = 4.499E-10 VA = 7.500E+01 NE = 2.00E+00 TF = 1.400E-10 PE = 5.400E-01 MC = 2.100E-01	RB = 1.908E+02 UB = 2.000E+01 IKR = 4.000E-02 TR = 1.150E-07 ME = 3.700E-01 EG = 1.100E+00
RN8C	NPN	BF = 2.500E+02 RC = 1.600E+02 IK = 4.000E-01 C4 = 4.101E+01 CCS = 4.200E-12 CJC = 3.800E-12	BR = 1.224E+01 RE = 0.000E+00 C2 = 1.789E+00 NC = 1.450E+00 CJE = 6.200E-12 PC = 2.700E-01	IS = 8.398E-10 VA = 7.500E+01 NE = 2.000E+00 TF = 1.400E-10 PE = 6.400E-01 MC = 2.100E-01	RB = 1.140E+02 UB = 2.000E+01 IKR = 2.000E-02 TR = 1.150E-07 ME = 3.700E-01 EG = 1.100E+00
RF0	PNP	BF = 1.950E+02 RC = 2.850E+02 IK = 2.500E-02 C4 = 4.101E+01 CCS = 2.000E-13 CJC = 6.000E-13	BR = 1.062E+01 RE = 0.000E+00 C2 = 1.450E+00 NC = 1.200E-13 CJE = 5.200E-01 PC = 1.500E-01	IS = 3.937E-11 VA = 6.000E+01 NE = 2.000E+00 TF = 3.500E-10 PE = 4.900E-01 MC = 3.300E-01	RB = 3.600E+02 UB = 2.000E+01 IKR = 2.000E-02 TR = 2.000E-07 ME = 2.600E-01 EG = 1.110E+00

RP1	PNP	IS = 1.662E+01 VB = 6.000E+01 IKR = 1.000E-02 TR = 5.200E-07 ME = 2.600E-01 EG = 1.110E+00	IS = 7.873E-11 VB = 6.000E+01 IKR = 1.000E-02 TR = 5.200E-07 ME = 2.600E-01 EG = 1.110E+00	IS = 3.000E+02 VB = 2.000E+01 IKR = 1.000E-02 TR = 5.200E-07 ME = 2.600E-01 EG = 1.110E+00		
	BF = 1.950E+02 RC = 1.080E+03 IK = 1.000E-02 C4 = 4.101E+01 CCS = 2.500E-13 CJC = 8.600E-13	BF = 1.062E+01 RE = 0.000E+00 C2 = 1.789E+00 NC = 1.450E+00 CJE = 3.700E-12 PC = 1.500E-01	IS = 3.149E-10 VB = 6.000E+01 NE = 2.000E+00 TF = 3.500E-10 PE = 4.900E-01 NC = 3.300E-01	IS = 9.000E+01 VB = 2.000E+01 IKR = 4.000E-02 TR = 5.200E-07 NE = 2.600E-01 EG = 1.110E+00		
	RP4	PNP	BF = 1.950E+02 RC = 1.200E+02 IK = 2.000E-01 C4 = 4.101E+01 CCS = 4.400E-13 CJC = 2.500E-12	BF = 1.062E+01 RE = 0.000E+00 C2 = 1.789E+00 NC = 1.450E+00 CJE = 7.000E-12 PC = 1.500E-01	IS = 3.149E-10 VB = 6.000E+01 NE = 2.000E+00 TF = 3.500E-10 PE = 4.900E-01 NC = 3.300E-01	IS = 9.000E+01 VB = 2.000E+01 IKR = 4.000E-02 TR = 5.200E-07 NE = 2.600E-01 EG = 1.110E+00
	PP8C	PNP	BF = 1.950E+02 RC = 2.320E+02 IK = 4.000E-01 C4 = 4.101E+01 CCS = 1.200E-12 CJC = 4.000E-12	BF = 1.062E+01 RE = 0.000E+00 C2 = 1.789E+00 NC = 1.450E+00 CJE = 7.000E-12 PC = 1.500E-01	IS = 6.299E-10 VB = 6.000E+01 NE = 2.000E+00 TF = 3.500E-10 PE = 4.900E-01 NC = 3.300E-01	IS = 6.299E-10 VB = 6.000E+01 IKR = 8.000E-02 TR = 5.200E-07 ME = 2.600E-01 EG = 1.110E+00
	DZR	ZENER DIODE MODEL	NAME	NAME	NAME	
	IS = 5.624E-11 CJO = 4.500E-13 PT = 3.000E+00 BU = 6.466E+00	RS = 7.500E+01 PB = 6.400E-01 KF = 0.000E+00 IVU = 5.000E-04	N = 1.000E+00 M = 3.700E-01 AF = 1.000E+00	TT = 1.400E-10 EQ = 1.110E+00 FC = 5.000E-01		

(TEMPERATURE -55 DEGREES C)

----- BJT MODELS -----

NAME	TYPE	BR =	RE =	C2 =	NC =	NE =	TF =	PE =	MC =	IS =	VA =	NE =	TF =	PE =	MC =	IS =	VA =	NE =	TF =	PE =	MC =	IS =	VA =	NE =	TF =	PE =	MC =
RN1LC	NPN	4.590E+00	0.000E+00	2.434E+06	1.450E+08	2.000E+01	1.400E-16	1.000E+00	2.100E-01	5.835E-23	7.500E+01	2.000E+02	4.300E-03	3.700E-01	1.110E+00	2.688E+02	2.000E+01	1.000E-02	4.300E-03	3.700E-01	1.110E+00	2.688E+02	2.000E+01	1.000E-02	4.300E-03	3.700E-01	1.110E+00
BF =	1.600E+02																										
RC =	2.424E+02																										
IK =	5.000E-02																										
C4 =	1.406E+04																										
CCS =	4.500E-13																										
CJC =	8.000E-13																										
RP1LC	PNP	5.400E+00	0.000E+00	2.484E+06	1.450E+08	2.000E+01	1.400E-16	1.000E+00	2.100E-01	4.084E-23	6.000E+01	2.000E+02	4.300E-03	3.700E-01	1.110E+00	2.100E+02	2.000E+01	1.000E-02	4.300E-03	3.700E-01	1.110E+00	2.100E+02	2.000E+01	1.000E-02	4.300E-03	3.700E-01	1.110E+00
BF =	8.025E+01																										
RC =	3.000E+02																										
IK =	5.000E-02																										
C4 =	1.406E+04																										
CCS =	4.500E-13																										
CJC =	8.000E-13																										
RN0	NPN	4.590E+00	0.000E+00	2.484E+06	1.450E+08	2.000E+01	1.400E-16	1.000E+00	2.100E-01	4.084E-23	6.000E+01	2.000E+02	4.300E-03	3.700E-01	1.110E+00	2.100E+02	2.000E+01	1.000E-02	4.300E-03	3.700E-01	1.110E+00	2.100E+02	2.000E+01	1.000E-02	4.300E-03	3.700E-01	1.110E+00
BF =	1.600E+02																										
RC =	6.318E+02																										
IK =	2.500E-02																										
C4 =	1.406E+04																										
CCS =	2.000E-13																										
CJC =	5.400E-13																										

RN1	NPN	IS= 5.835E-23 UB= 2.699E+02 IKR= 2.000E+01 TR= 4.300E-08 ME= 3.700E-01 EG= 1.100E+00
	BF	4.590E+00 RE= 0.600E+00 C2= 2.484E+06 NC= 2.1450E+09 CJE= 1.8200E-13 PC= 6.300E-01
	RC	1.146E+02 RE= 5.000E-02 C2= 5.000E+06 NC= 1.496E+04 C4= 1.500E-13 CCS= 2.500E-13 CJC= 8.000E-13
	IK	
	C4	
	CCS	
	CJC	
	BR	4.590E+00 RE= 0.600E+00 C2= 2.484E+06 NC= 1.450E+09 CJE= 3.200E-12 PC= 6.300E-01
	RC	1.050E+02 RE= 2.000E-01 C2= 1.406E+04 NC= 4.000E-13 C4= 4.000E-13 CCS= 2.300E-12 CJC= 2.300E-12
	IK	
RN4	NPN	IS= 2.334E-22 UB= 1.336E+02 IKR= 2.000E+01 TR= 4.300E-08 ME= 3.700E-01 EG= 1.100E+00
	BF	4.590E+00 RE= 0.600E+00 C2= 2.484E+06 NC= 1.450E+09 CJE= 3.200E-12 PC= 6.300E-01
	RC	1.050E+02 RE= 2.000E-01 C2= 1.406E+04 NC= 4.000E-13 C4= 4.000E-13 CCS= 2.300E-12 CJC= 2.300E-12
	IK	
	C4	
	CCS	
	CJC	
	BR	4.590E+00 RE= 0.600E+00 C2= 2.484E+06 NC= 1.450E+09 CJE= 6.200E-12 PC= 6.300E-01
	RC	1.050E+02 RE= 2.000E-01 C2= 1.406E+04 NC= 4.000E-13 C4= 4.000E-13 CCS= 3.300E-12 CJC= 3.300E-12
	IK	
RN8C	NPN	IS= 4.668E-22 UB= 7.980E+01 IKR= 2.000E+01 TR= 4.300E-08 ME= 3.700E-01 EG= 1.100E+00
	BF	4.590E+00 RE= 0.600E+00 C2= 2.484E+06 NC= 1.450E+09 CJE= 6.200E-12 PC= 6.300E-01
	RC	1.050E+02 RE= 2.000E-01 C2= 1.406E+04 NC= 4.000E-13 C4= 4.000E-13 CCS= 3.300E-12 CJC= 3.300E-12
	IK	
	C4	
	CCS	
	CJC	
	BR	4.590E+00 RE= 0.600E+00 C2= 2.484E+06 NC= 1.450E+09 CJE= 6.300E-01 PC= 6.300E-01
	RC	1.050E+02 RE= 2.000E-01 C2= 1.406E+04 NC= 4.000E-13 C4= 4.000E-13 CCS= 3.300E-12 CJC= 3.300E-12
	IK	
RP0	PNP	IS= 2.042E-23 UB= 2.520E+02 IKR= 2.000E+01 TR= 5.000E-03 ME= 2.600E-01 EG= 1.100E+00
	BF	8.025E+01 RE= 0.568E+02 C2= 2.500E-02 NC= 1.406E+04 C4= 1.406E+04 CCS= 2.000E-13 CJC= 6.000E-13
	RC	8.568E+01 RE= 2.500E-02 C2= 2.450E+06 NC= 5.200E-13 CJE= 5.200E-13 PC= 5.100E-01
	IK	
	C4	
	CCS	
	CJC	
	BR	5.400E+00 RE= 0.568E+00 C2= 2.434E+06 NC= 1.450E+06 CJE= 5.100E-01 PC= 5.300E-01
	RC	8.025E+01 RE= 2.000E+00 C2= 2.500E-02 NC= 3.500E-10 PE= 3.500E-01 MC= 3.300E-01
	IK	

RP1	PNP	BR = 5.400E+00 RE = 0.000E+00 C2 = 2.484E+06 NC = 1.450E+00 CJE = 2.500E-13 PC = 5.100E-01	IS = 4.084E-23 UA = 6.000E+01 NE = 5.000E-10 TF = 5.000E-01 PE = 3.300E-01 MC = 1.100E+00	RB = 2.190E+02 UB = 2.000E+01 IKR = 1.000E-02 TR = 3.040E-07 ME = 2.600E-01 EG = 1.110E+00
	RP4	BR = 5.400E+00 RE = 0.000E+00 C2 = 2.484E+06 NC = 1.450E+00 CJE = 3.700E-12 PC = 5.100E-01	IS = 1.634E-22 UA = 6.000E+01 NE = 3.500E-10 TF = 8.500E-01 PE = 3.300E-01 MC = 1.110E+00	RB = 6.700E+01 UB = 2.000E+01 IKR = 4.000E-02 TR = 7.040E-07 ME = 2.600E-01 EG = 1.110E+00
RP8C	PNP	BR = 5.400E+00 RE = 0.000E+00 C2 = 2.484E+06 NC = 1.450E+00 CJE = 7.300E-12 PC = 5.100E-01	IS = 3.267E-22 UA = 6.000E+01 NE = 3.500E-10 TF = 8.500E-01 PE = 3.300E-01 MC = 1.110E+00	RB = 3.108E+01 UB = 2.000E+01 IKR = 8.000E-02 TR = 3.040E-07 ME = 2.600E-01 EG = 1.110E+00
	ZENER DIODE MODEL	NAME DZR IS = 2.917E-23 CJO = 4.500E-13 PT = 3.000E+00 BV = 5.992E+00	RS = 7.500E+01 PB = 1.000E+00 KF = 0.000E+00 IBU = 5.000E-04	TT = 1.400E-10 EQ = 1.110E+00 FC = 5.000E-01

POST-RADIATION GUMMEL-POON MODEL PARAMETERS FOR SPICE II CIRCUIT
SIMULATION OF THE D1NS PHOTOPREAMPLIFIER (TEMPERATURE 25 DEGREES C)

----- BJT MODELS -----

NAME	TYPE	BR	RE	C2	NC	CJE	PC	BR	RE	C2	NC	CJE	PC	BR	RE	C2	NC	CJE	PC	BR	RE	C2	NC	CJE	PC	BR	RE	C2	NC	CJE	PC	
RH1LC	NPN	8F = 4.2000E+01	BR = 9.0000E+00	RE = 9.0000E+00	C2 = 9.0220E+01	NC = 1.4500E+00	CJE = 8.2000E-13	PC = 4.7000E-01	IS = 1.0000E-15	VA = 7.5000E+01	HE = 1.4480E+00	TF = 1.4000E-10	PE = 8.4000E-01	MC = 2.1000E-01	RB = 3.2000E+02	UB = 2.0000E+01	IKR = 1.0000E-02	TR = 7.5000E-08	ME = 3.7000E-01	EG = 1.1100E+00	RB = 3.2000E+02	UB = 2.0000E+01	IKR = 1.0000E-02	TR = 7.5000E-08	ME = 3.7000E-01	EG = 1.1100E+00	RB = 3.2000E+02	UB = 2.0000E+01	IKR = 1.0000E-02	TR = 7.5000E-08	ME = 3.7000E-01	EG = 1.1100E+00
RPI1LC	PNP	8F = 2.9550E+01	BR = 9.0000E+00	RE = 9.0000E+00	C2 = 8.3740E+01	NC = 1.4500E+00	CJE = 9.5000E-13	PC = 3.5000E-01	IS = 7.0000E-16	VA = 6.0000E+01	HE = 1.3810E+00	TF = 3.5000E-10	PE = 6.9000E-01	MC = 3.3000E-01	RB = 2.5000E+02	UB = 2.0000E+01	IKR = 1.0000E-02	TR = 4.6000E-07	ME = 2.6000E-01	EG = 1.1100E+00	RB = 2.5000E+02	UB = 2.0000E+01	IKR = 1.0000E-02	TR = 4.6000E-07	ME = 2.6000E-01	EG = 1.1100E+00	RB = 2.5000E+02	UB = 2.0000E+01	IKR = 1.0000E-02	TR = 4.6000E-07	ME = 2.6000E-01	EG = 1.1100E+00
RH0	NPN	BF = 4.200E+01	BR = 9.0000E+00	RE = 9.0000E+00	C2 = 9.0230E+01	NC = 1.4500E+00	CJE = 4.500E-13	PC = 4.7000E-01	IS = 5.0000E-16	VA = 7.5000E+01	HE = 1.4430E+00	TF = 1.4000E-10	PE = 8.4000E-01	MC = 2.1000E-01	RB = 3.2000E+02	UB = 2.0000E+01	IKR = 1.0000E-02	TR = 7.5000E-08	ME = 3.7000E-01	EG = 1.1100E+00	RB = 3.2000E+02	UB = 2.0000E+01	IKR = 1.0000E-02	TR = 7.5000E-08	ME = 3.7000E-01	EG = 1.1100E+00	RB = 3.2000E+02	UB = 2.0000E+01	IKR = 1.0000E-02	TR = 7.5000E-08	ME = 3.7000E-01	EG = 1.1100E+00

RN1	NPN	BR= 9.000E+00 RE= 9.000E+00 C2= 0.29E+01 NC= 1.450E+00 CJE= 8.200E-13 PC= 4.700E-01	IS= 1.000E-15 UH= 1.500E+01 NE= 1.448E+00 TF= 1.400E-10 PE= 8.400E-01 MC= 2.100E-01	RB= 3.200E+02 UB= 2.000E+01 IKR= 1.000E-02 TR= 7.500E-03 ME= 3.700E-01 EG= 1.110E+00
	NPN	BR= 9.000E+01 RE= 9.000E+02 C2= 0.29E+01 NC= 1.450E+00 CJE= 8.200E-13 PC= 4.700E-01	IS= 4.000E-15 UH= 7.500E+01 NE= 1.448E+00 TF= 1.400E-10 PE= 8.400E-01 MC= 2.100E-01	RB= 1.590E+02 UB= 2.000E+01 IKR= 4.000E-02 TR= 7.500E-03 ME= 3.700E-01 EG= 1.110E+00
	NPN	BR= 9.000E+01 RE= 9.000E+02 C2= 0.29E+01 NC= 1.450E+00 CJE= 8.200E-13 PC= 4.700E-01	IS= 3.000E-15 UH= 7.500E+01 NE= 1.448E+00 TF= 1.400E-10 PE= 8.400E-01 MC= 2.100E-01	RB= 9.500E+01 UB= 9.000E+01 IKR= 8.000E-02 TR= 7.500E-03 ME= 3.700E-01 EG= 1.110E+00
	NPN	BR= 9.000E+01 RE= 9.000E+02 C2= 0.29E+01 NC= 1.450E+00 CJE= 8.200E-13 PC= 4.700E-01	IS= 3.000E-15 UH= 7.500E+01 NE= 1.448E+00 TF= 1.400E-10 PE= 8.400E-01 MC= 2.100E-01	RB= 9.500E+01 UB= 9.000E+01 IKR= 8.000E-02 TR= 7.500E-03 ME= 3.700E-01 EG= 1.110E+00
	NPN	BR= 9.000E+01 RE= 9.000E+02 C2= 0.29E+01 NC= 1.450E+00 CJE= 8.200E-13 PC= 4.700E-01	IS= 3.000E-15 UH= 7.500E+01 NE= 1.448E+00 TF= 1.400E-10 PE= 8.400E-01 MC= 2.100E-01	RB= 9.500E+01 UB= 9.000E+01 IKR= 8.000E-02 TR= 7.500E-03 ME= 3.700E-01 EG= 1.110E+00
	PNP	BR= 9.000E+01 RE= 9.000E+02 C2= 0.29E+01 NC= 1.450E+00 CJE= 8.200E-12 PC= 2.300E-12	IS= 3.000E-15 UH= 7.500E+01 NE= 1.448E+00 TF= 1.400E-10 PE= 8.400E-01 MC= 2.100E-01	RB= 9.500E+01 UB= 9.000E+01 IKR= 8.000E-02 TR= 7.500E-03 ME= 3.700E-01 EG= 1.110E+00
	PNP	BR= 9.000E+01 RE= 9.000E+02 C2= 0.29E+01 NC= 1.450E+00 CJE= 8.200E-12 PC= 2.300E-12	IS= 3.000E-15 UH= 7.500E+01 NE= 1.448E+00 TF= 1.400E-10 PE= 8.400E-01 MC= 2.100E-01	RB= 9.500E+01 UB= 9.000E+01 IKR= 8.000E-02 TR= 7.500E-03 ME= 3.700E-01 EG= 1.110E+00
	PNP	BR= 9.000E+01 RE= 9.000E+02 C2= 0.29E+01 NC= 1.450E+00 CJE= 8.200E-12 PC= 2.300E-12	IS= 3.000E-15 UH= 7.500E+01 NE= 1.448E+00 TF= 1.400E-10 PE= 8.400E-01 MC= 2.100E-01	RB= 9.500E+01 UB= 9.000E+01 IKR= 8.000E-02 TR= 7.500E-03 ME= 3.700E-01 EG= 1.110E+00
	PNP	BR= 9.000E+01 RE= 9.000E+02 C2= 0.29E+01 NC= 1.450E+00 CJE= 8.200E-12 PC= 2.300E-12	IS= 3.000E-15 UH= 7.500E+01 NE= 1.448E+00 TF= 1.400E-10 PE= 8.400E-01 MC= 2.100E-01	RB= 9.500E+01 UB= 9.000E+01 IKR= 8.000E-02 TR= 7.500E-03 ME= 3.700E-01 EG= 1.110E+00
	PNP	BR= 9.000E+01 RE= 9.000E+02 C2= 0.29E+01 NC= 1.450E+00 CJE= 8.200E-12 PC= 2.300E-12	IS= 3.000E-15 UH= 7.500E+01 NE= 1.448E+00 TF= 1.400E-10 PE= 8.400E-01 MC= 2.100E-01	RB= 9.500E+01 UB= 9.000E+01 IKR= 8.000E-02 TR= 7.500E-03 ME= 3.700E-01 EG= 1.110E+00

RP1	PNP	BR = 9.000E+00 RE = 0.000E+00 C2 = 8.374E+01 NC = 1.450E+00 CJE = 9.500E-13 PC = 3.500E-01	IS = 7.000E-16 U4 = 6.000E+01 NE = 1.381E+00 TF = 3.500E-10 PE = 6.900E-01 MC = 3.300E-01	RB = 2.500E+02 UB = 2.000E+01 IKR = 1.000E-02 TR = 4.000E-07 ME = 2.600E-01 EG = 1.110E+00
RP4	PNP	BR = 9.000E+00 RE = 0.000E+00 C2 = 8.374E+01 NC = 1.450E+00 CJE = 3.700E-12 PC = 3.500E-01	IS = 2.800E-15 U4 = 6.000E+01 NE = 1.381E+00 TF = 3.500E-10 PE = 6.900E-01 MC = 3.300E-01	RB = 7.500E+01 UB = 2.000E+01 IKR = 4.000E-02 TR = 4.000E-07 ME = 2.600E-01 EG = 1.110E+00
RP8C	PNP	BR = 9.000E+00 RE = 0.000E+00 C2 = 8.374E+01 NC = 1.450E+00 CJE = 7.300E-12 PC = 3.500E-01	IS = 5.600E-15 U4 = 6.000E+01 NE = 1.381E+00 TF = 3.500E-10 PE = 6.900E-01 MC = 3.300E-01	RB = 3.700E+01 UB = 2.000E+01 IKR = 3.000E-02 TR = 4.000E-07 ME = 2.600E-01 EG = 1.110E+00
	NAME	DZR	IS = 5.000E-16 CJO = 4.500E-13 PT = 3.000E+00 BV = 6.200E+00	RB = 7.500E+01 PB = 8.400E-01 KF = 0.000E+00 IU = 5.000E-04
				TT = 1.400E-10 EQ = 1.110E+00 FC = 5.000E-01

---- ZENER DIODE MODEL ----

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APPENDIX 2.0

DC CIRCUIT SIMULATIONS

2.1 25° Operating Points

2.2 125° " "

2.3 -55° " "

2.4 25° Post Neutron Operating Points

1 DINS PHOTOPREAMPLIFIER OPERATING POINTS (TEMPERATURE 25 DEGREES C)
 2
 3
 4 ----- VOLTAGE SUPPLY CURRENTS -----
 5
 6 NAME Currnt NAME Currnt
 7 VPOS -3.299E-07 VNEG 3.754E-03 TOTAL POWER = 106 MW (ONE CHANNEL)
 8
 9
 10 ----- ZENER DIODE -----
 11
 12 NAME: DZ1 MODEL: DZR
 13
 14 ID=-2.761E-04 VD=-6.205E+00 REG= 9.305E+01 CAP= 1.710E-1
 15
 16 ----- BJT'S -----
 17
 18 NAME: Q1 MODEL: RPO
 19
 20 IB=-4.831E-07 IC=-6.936E-05 VBF=-6.645E-01 VRC= 1.222E+0
 21 VCE=-1.288E+01 BFTADC= 1.436E+02 GM= 2.689E-03 RPI= 5.841E+0
 22 RO= 1.011E+06 CPI= 1.583E-12 CMU= 1.845E-13 BETAAC= 1.571E+0
 23 FT= 2.422E+08
 24
 25 NAME: Q2 MODEL: RPO
 26
 27 IB=-4.826E-07 IC=-6.935E-05 VBF=-6.645E-01 VRC= 1.229E+0
 28 VCF=-1.295E+01 BFTADC= 1.437E+02 GM= 2.689E-03 RPI= 5.847E+0
 29 RO= 1.012E+06 CPI= 1.582E-12 CMU= 1.842E-13 BETAAC= 1.572E+0
 30 FT= 2.423E+08
 31
 32 NAME: Q3 MODEL: RNO
 33
 34 IB= 3.042E-07 IC= 4.917E-05 VBF= 6.471E-01 VRC=-1.295E+0
 35 VCE= 1.360E+01 BFTADC= 1.616E+02 GM= 1.908E-03 RPI= 9.873E+0
 36 RO= 1.738E+06 CPI= 9.334E-13 CMU= 2.673E-13 BETAAC= 1.884E+0
 37 FT= 2.529E+08
 38
 39 NAME: Q4 MODEL: RN1
 40
 41 IB= 5.137E-07 IC= 6.907E-05 VBF= 6.420E-01 VRC=-7.156E-0
 42 VCE= 1.358E+00 BFTADC= 1.345E+02 GM= 2.680E-03 RPI= 5.922E+0
 43 RO= 1.061E+06 CPI= 1.653E-12 CMU= 6.644E-13 BETAAC= 1.587E+0
 44 FT= 1.841E+08
 45
 46 NAME: Q5 MODEL: RN1
 47
 48 IB= 5.140E-07 IC= 6.905E-05 VBE= 6.420E-01 VRC=-6.471E-0
 49 VCE= 1.289E+00 BFTADC= 1.343E+02 GM= 2.679E-03 RPI= 5.918E+0
 50 RO= 1.060E+06 CPI= 1.653E-12 CMU= 6.731E-13 BETAAC= 1.586E+0
 51 FT= 1.833E+08
 52
 53 NAME: Q6 MODEL: RN1
 54
 55 IB= 2.192E-07 IC= 2.423E-05 VBE= 6.151E-01 VRC=-3.142E-0

56 VCE= 9.293E-01 BETAOC= 1.105E+02 GM= 9.409E-04 RPI= 1.495E+
 57 RO= 3.013E+06 CPI= 1.378E-12 CMU= 7.217E-13 BETAAC= 1.406E+
 58 FT= 7.133E+07
 59

60 NAME: Q7 MODEL: RN1

61

62 IB= 2.192E-07 IC= 2.423E-05 VBE= 6.151E-01 VBC=-3.142E-
 63 VCE= 9.293E-01 BETAOC= 1.105E+02 GM= 9.409E-04 RPI= 1.495E+
 64 RO= 3.013E+06 CPI= 1.378E-12 CMU= 7.217E-13 BETAAC= 1.406E+
 65 FT= 7.133E+07

66

67 NAME: Q8 MODEL: RP0

68

69 IB=-9.047E-07 IC=-1.397E-04 VBE=-6.871E-01 VBC= 1.392E+
 70 VCE=-1.461E+01 BETAOC= 1.544E+02 GM= 5.404E-03 RPI= 3.044E+
 71 RO= 5.132E+05 CPI= 2.381E-12 CMU= 1.773E-13 BETAAC= 1.645E+
 72 FT= 3.362E+08

73

74 NAME: Q9 MODEL: RP1

75

76 IB=-2.244E-06 IC=-2.855E-04 VBE=-6.883E-01 VBC= 6.424E-
 77 VCE=-1.331E+00 BETAOC= 1.272E+02 GM= 1.103E-02 RPI= 1.219E+
 78 RO= 2.042E+05 CPI= 5.459E-12 CMU= 6.855E-13 BETAAC= 1.344E+
 79 FT= 2.857E+08

80

81 NAME: Q10 MODEL: RP1

82

83 IB=-4.478E-07 IC=-5.971E-05 VBE=-6.424E-01 VBC= 1.328E+
 84 VCE=-1.392E+01 BETAOC= 1.333E+02 GM= 2.318E-03 RPI= 6.560E+
 85 RO= 1.194E+06 CPI= 2.078E-12 CMU= 2.572E-13 BETAAC= 1.521E+
 86 FT= 1.580E+08

87

88 NAME: Q11 MODEL: RNO

89

90 IB= 1.381E-06 IC= 2.859E-04 VBE= 6.910E-01 VBC=-1.998E-
 91 VCE= 2.067E+01 BFTADC= 2.071E+02 GM= 1.101E-02 RPI= 2.010E+
 92 RO= 3.221E+05 CPI= 2.001E-12 CMU= 2.453E-13 BETAAC= 2.214E-
 93 FT= 7.803E+08

94

95 NAME: Q12 MODEL: RNO

96

97 IB= 2.961E-07 IC= 4.760E-05 VBE= 6.443E-01 VBC=-1.288E-
 98 VCE= 1.353E+01 BETAOC= 1.608E+02 GM= 1.847E-03 RPI= 1.017E-
 99 RO= 1.794E+06 CPI= 9.256E-13 CMU= 2.676E-13 BETAAC= 1.877E-
 100 FT= 2.463E+08

101

102 NAME: Q13 MODEL: RN1

103

104 IB= 3.705E-07 IC= 4.652E-05 VBE= 6.319E-01 VBC=-3.835E-
 105 VCE= 1.015E+00 BETAOC= 1.256E+02 GM= 1.806E-03 RPI= 8.428E-
 106 RO= 1.569E+06 CPI= 1.518E-12 CMU= 7.115E-13 BETAAC= 1.522E-
 107 FT= 1.289E+08

108

109 NAME: Q14 MODEL: RN1

110

W1

28 JUN 79

21:51:17

HARRIS SLASH/8

PAGE 1

111	IB = 1.812E-06	IC = 2.869E-04	VBE = 6.793E-01	VBC = -6.337E+0
112	VCE = 1.313E+00	BETADC = 1.584E+02	GM = 1.108E-02	RPI = 1.559E+0
113	RO = 2.540E+05	CPI = 2.919E-12	CMII = 6.970E-13	BETAAC = 1.728E+0
114	FT = 4.878E+08			
115	<hr/>			
116	NAME: Q15	MODEL: RP0		
117	<hr/>			
118	IB = -1.573E-06	IC = -2.474E-04	VBE = -6.974E-01	VBC = 1.325E+0
119	VCE = -1.395E+01	BETADC = 1.573E+02	GM = 9.538E-03	RPI = 1.723E+0
120	RO = 2.862E+05	CPI = 3.668E-12	CMII = 1.809E-13	BETAAC = 1.643E+0
121	FT = 3.944E+08			
122	<hr/>			
123	NAME: Q16	MODEL: RN1LC		
124	<hr/>			
125	IB = 1.566E-06	IC = 2.428E-04	VBE = 6.751E-01	VBC = 0.000E+0
126	VCE = 6.751E-01	BETADC = 1.550E+02	GM = 9.387E-03	RPI = 1.815E+0
127	RO = 2.981E+05	CPI = 2.675E-12	CMII = 8.401E-13	BETAAC = 1.704E+0
128	FT = 4.250E+08			
129	<hr/>			
130	NAME: Q17	MODEL: RP1LC		
131	<hr/>			
132	IB = -1.938E-06	IC = -2.424E-04	VBE = -6.842E-01	VBC = 0.000E+0
133	VCE = -6.842E-01	BETADC = 1.251E+02	GM = 9.372E-03	RPI = 1.418E+0
134	RO = 2.385E+05	CPI = 4.872E-12	CMII = 9.888E-13	BETAAC = 1.329E+0
135	FT = 2.545E+08			
136	<hr/>			
137	NAME: Q18	MODEL: RN1		
138	<hr/>			
139	IB = 3.919E-07	IC = 5.860E-05	VBE = 6.337E-01	VBC = -1.328E+0
140	VCE = 1.391E+01	BETADC = 1.495E+02	GM = 2.275E-03	RPI = 7.927E+0
141	RO = 1.465E+06	CPI = 1.538E-12	CMII = 3.940E-13	BETAAC = 1.804E+0
142	FT = 1.874E+08			
143	<hr/>			
144	NAME: Q19	MODEL: RN1		
145	<hr/>			
146	IB = 1.377E-06	IC = 2.479E-04	VBE = 6.714E-01	VBC = -1.285E+0
147	VCE = 1.352E+01	BETADC = 1.800E+02	GM = 9.595E-03	RPI = 2.077E+0
148	RO = 3.435E+05	CPI = 2.489E-12	CMII = 3.975E-13	BETAAC = 1.993E+0
149	FT = 5.290E+08			
150	<hr/>			
151	NAME: Q20	MODEL: RN1LC		
152	<hr/>			
153	IB = 1.595E-06	IC = 2.477E-04	VBE = 6.756E-01	VBC = 0.000E+0
154	VCE = 6.756E-01	BETADC = 1.553E+02	GM = 9.577E-03	RPI = 1.781E+0
155	RO = 2.921E+05	CPI = 2.704E-12	CMII = 8.410E-13	BETAAC = 1.706E+0
156	FT = 4.299E+08			
157	<hr/>			
158	NAME: Q21	MODEL: RN4		
159	<hr/>			
160	IB = 3.083E-06	IC = 5.249E-04	VBE = 6.545E-01	VBC = -1.430E+0
161	VCE = 1.495E+01	BETADC = 1.703E+02	GM = 2.036E-02	RPI = 9.591E+0
162	RO = 1.653E+05	CPI = 7.467E-12	CMII = 1.117E-12	BETAAC = 1.952E+0
163	FT = 3.775E+08			
164	<hr/>			
165	NAME: Q22	MODEL: RP4		

166

167 $IB = -3.581E-06$ $IC = -5.253E-04$ $VBF = -6.625E-01$ $VBC = 1.429E+0$
 168 $VCE = -1.495E+01$ $BETAOC = 1.467E+02$ $GM = 2.037E-02$ $RPI = 7.906E+0$
 169 $RO = 1.374E+05$ $CPI = 1.145E-11$ $CMU = 7.315E-13$ $BETAAC = 1.610E+0$
 170 $FT = 2.661E+08$

171

172 NAME: Q23 MODEL: RN1LC

173

174 $IB = 5.178E-07$ $IC = 6.906E-05$ $VBF = 6.423E-01$ $VBC = 0.000E+0$
 175 $VCE = 6.423E-01$ $BET4OC = 1.334E+02$ $GM = 2.680E-03$ $RPI = 5.871E+0$
 176 $RO = 1.051E+06$ $CPI = 1.657E-12$ $CMU = 8.103E-13$ $BETAAC = 1.573E+0$
 177 $FT = 1.729E+08$

178

179 NAME: Q24 MODEL: RN1LC

180

181 $IB = 5.177E-07$ $IC = 6.905E-05$ $VBE = 6.423F-01$ $VBC = 0.000E+0$
 182 $VCE = 6.423E-01$ $BET4OC = 1.334E+02$ $GM = 2.679E-03$ $RPI = 5.872E+0$
 183 $RO = 1.051E+06$ $CPI = 1.657E-12$ $CMU = 8.103E-13$ $BETAAC = 1.573E+0$
 184 $FT = 1.729E+08$

185

186 NAME: Q25 MODEL: RN1LC

187

188 $IB = 4.287E-07$ $IC = 5.518E-05$ $VBF = 6.365E-01$ $VBC = 0.000E+0$
 189 $VCE = 6.365E-01$ $BET4OC = 1.287E+02$ $GM = 2.142E-03$ $RPI = 7.195E+0$
 190 $RO = 1.315E+06$ $CPI = 1.573E-12$ $CMU = 8.082E-13$ $BETAAC = 1.541E+0$
 191 $FT = 1.432E+08$

192

193 NAME: Q26 MODEL: RP1LC

194

195 $IB = -4.988E-07$ $IC = -5.494E-05$ $VBF = -6.455E-01$ $VBC = 0.000E+0$
 196 $VCE = -6.455E-01$ $BET4OC = 1.101E+02$ $GM = 2.132E-03$ $RPI = 5.853E+0$
 197 $RO = 1.056E+06$ $CPI = 2.170E-12$ $CMU = 8.834E-13$ $BETAAC = 1.248E+0$
 198 $FT = 1.111E+08$

199

200 NAME: Q27 MODEL: RN1LC

201

202 $IB = 1.751E-06$ $IC = 2.744E-04$ $VBF = 6.783E-01$ $VBC = 0.000E+0$
 203 $VCE = 6.783E-01$ $BET4OC = 1.567E+02$ $GM = 1.060E-02$ $RPI = 1.615E+0$
 204 $RO = 2.637E+05$ $CPI = 2.859E-12$ $CMU = 8.462E-13$ $BETAAC = 1.712E+0$
 205 $FT = 4.554E+08$

206

207 NAME: Q28 MODEL: RN1LC

208

209 $IB = 1.751E-06$ $IC = 2.744E-04$ $VBF = 6.783E-01$ $VBC = 0.000E+0$
 210 $VCE = 6.783E-01$ $BET4OC = 1.567E+02$ $GM = 1.060E-02$ $RPI = 1.615E+0$
 211 $RO = 2.637E+05$ $CPI = 2.859E-12$ $CMU = 8.462E-13$ $BETAAC = 1.712E+0$
 212 $FT = 4.554E+08$

213

214 NAME: Q29 MODEL: RN1LC

215

216 $IB = 1.751E-06$ $IC = 2.744E-04$ $VBF = 6.783F-01$ $VBC = 0.000E+0$
 217 $VCE = 6.783E-01$ $BET4OC = 1.567F+02$ $GM = 1.060E-02$ $RPI = 1.615E+0$
 218 $RO = 2.637E+05$ $CPI = 2.859E-12$ $CMU = 8.462E-13$ $BETAAC = 1.712F+0$
 219 $FT = 4.554E+08$

220

221 NAME: Q30 MODEL: RNO
 222
 223 IB=-7.403E-11 IC= 7.431E-11 VBE= 0.000E+00 VBC=-1.220E+
 224 VCE= 1.220E+01 BETADC=-1.004E+00 GM=-1.504E-14 RPI= 1.713E+
 225 RO= 3.877E+13 CPI= 4.500E-13 CMU= 2.704E-13 BETAAC=-2.575E-
 226 FT=-3.322E-03
 227
 228 NAME: Q31 MODEL: RNO
 229
 230 IB= 3.689E-07 IC= 6.291E-05 VBE= 6.529E-01 VBC=-1.497E+
 231 VCE= 1.562E+01 BETADC= 1.705E+02 GM= 2.440E-03 RPI= 8.038E+
 232 RO= 1.390E+06 CPI= 9.954E-13 CMU= 2.596E-13 BETAAC= 1.961E+
 233 FT= 3.094E+08
 234
 235 NAME: Q32 MODEL: RNO
 236
 237 IB= 3.689E-07 IC= 6.291E-05 VBE= 6.529E-01 VBC=-1.497E+
 238 VCE= 1.562E+01 BETADC= 1.705E+02 GM= 2.440E-03 RPI= 8.037E+
 239 RO= 1.390E+06 CPI= 9.954E-13 CMU= 2.596E-13 BETAAC= 1.961E+
 240 FT= 3.094E+08
 241
 242 NAME: Q33 MODEL: RNO
 243
 244 IB= 3.797E-07 IC= 6.376E-05 VBE= 6.537E-01 VBC=-1.325E+
 245 VCE= 1.390E+01 BETADC= 1.679E+02 GM= 2.473E-03 RPI= 7.793E+
 246 RO= 1.345E+06 CPI= 1.006E-12 CMU= 2.662E-13 BETAAC= 1.927E+
 247 FT= 3.094E+08
 248
 249 NAME: Q34 MODEL: RNO
 250
 251 IB= 3.797E-07 IC= 6.376E-05 VBE= 6.537E-01 VBC=-1.325E+
 252 VCE= 1.390E+01 BETADC= 1.679E+02 GM= 2.473E-03 RPI= 7.793E+
 253 RO= 1.345E+06 CPI= 1.006E-12 CMU= 2.662E-13 BETAAC= 1.927E+
 254 FT= 3.094E+08
 255
 256 NAME: Q35 MODEL: RPO
 257
 258 IB= 4.391E-12 IC=-4.405E-12 VBE= 0.000E+00 VBC= 1.034E+
 259 VCE=-1.034E+00 BETADC=-1.003E+00 GM=-9.387E-16 RPI= 2.447E+
 260 RO= 7.096E+13 CPI= 5.200E-13 CMU= 3.812E-13 BETAAC=-2.297E-
 261 FT=-1.658E-04
 262
 263 NAME: Q36 MODEL: RPI
 264
 265 IB= 8.782E-12 IC=-8.810E-12 VBE= 0.000E+00 VBC= 1.034E+
 266 VCE=-1.034E+00 BETADC=-1.003E+00 GM=-1.877E-15 RPI= 1.223E+
 267 RO= 3.548E+13 CPI= 9.500E-13 CMU= 5.464E-13 BETAAC=-2.297E-
 268 FT=-1.997E-04
 269
 270 NAME: Q37 MODEL: RPO
 271
 272 IB= 4.391E-12 IC=-4.405E-12 VBE= 0.000E+00 VBC= 1.034E+
 273 VCE=-1.034E+00 BETADC=-1.003E+00 GM=-9.387E-16 RPI= 2.447E+
 274 RO= 7.096E+13 CPI= 5.200E-13 CMU= 3.812E-13 BETAAC=-2.297E-
 275 FT=-1.658E-04

276
 277 NAME: Q38 MODEL: RN1
 278
 279 IB=-1.245E-11 IC= 1.249E-11 VBF= 0.000E+00 VBC=-1.026E+0
 280 VCE= 1.026E+00 BETADC=-1.003E+00 GM=-2.529E-15 RPI= 8.564E+1
 281 RO= 2.501E+13 CPI= 8.200E-13 CMU= 6.273E-13 BETAAC=-2.165E-0
 282 FT=-2.781E-04
 283
 284 NAME: Q39 MODEL: RN1
 285
 286 IB=-1.245E-11 IC= 1.249E-11 VBF= 0.000E+00 VBC=-1.026E+0
 287 VCE= 1.026E+00 BETADC=-1.003E+00 GM=-2.529E-15 RPI= 8.564E+1
 288 RO= 2.501E+13 CPI= 8.200E-13 CMU= 6.273E-13 BETAAC=-2.165E-0
 289 FT=-2.781E-04
 290
 291 NAME: Q40 MODEL: RN1
 292
 293 IB=-1.245E-11 IC= 1.249E-11 VBF= 0.000E+00 VBC=-1.026E+0
 294 VCE= 1.026E+00 BETADC=-1.003E+00 GM=-2.529E-15 RPI= 8.564E+1
 295 RO= 2.501E+13 CPI= 8.200E-13 CMU= 6.273E-13 BETAAC=-2.165E-0
 296 FT=-2.781E-04
 297
 298 NAME: Q41 MODEL: RN1
 299
 300 IB=-1.245E-11 IC= 1.249E-11 VBF= 0.000E+00 VBC=-1.026E+0
 301 VCE= 1.026E+00 BETADC=-1.003E+00 GM=-2.529E-15 RPI= 8.564E+1
 302 RO= 2.501E+13 CPI= 8.200E-13 CMU= 6.273E-13 BETAAC=-2.165E-0
 303 FT=-2.781E-04
 304
 305 NAME: Q42 MODEL: RP0
 306
 307 IB= 6.346E-11 IC=-6.372E-11 VBF= 0.000E+00 VBC= 1.494E+0
 308 VCE=-1.494E+01 BETADC=-1.004E+00 GM=-1.357E-14 RPI= 2.447E+1
 309 RO= 4.900E+13 CPI= 5.200E-13 CMU= 1.725E-13 BETAAC=-3.320E-0
 310 FT=-3.118E-03
 311
 312 NAME: Q43 MODEL: RN4
 313
 314 IB=-6.599E-11 IC= 6.621E-11 VBF= 0.000E+00 VBC=-1.359E+0
 315 VCE= 1.359E+00 BETADC=-1.003E+00 GM=-1.340E-14 RPI= 2.141E+1
 316 RO= 6.198E+12 CPI= 3.200E-12 CMU= 1.729E-12 BETAAC=-2.870E-0
 317 FT=-4.328E-04
 318
 319 NAME: Q44 MODEL: RNO
 320
 321 IB=-1.247E-11 IC= 1.252E-11 VBF= 0.000E+00 VBC=-2.056E+0
 322 VCE= 2.056E+00 BETADC=-1.003E+00 GM=-2.534E-15 RPI= 1.713E+1
 323 RO= 4.871E+13 CPI= 4.500E-13 CMU= 3.793E-13 BETAAC=-4.339E-0
 324 FT=-4.862E-04
 325
 326 NAME: Q45 MODEL: PNO
 327
 328 IB=-6.225E-12 IC= 6.245E-12 VBF= 0.000E+00 VBC=-1.026E+0
 329 VCE= 1.026E+00 BETADC=-1.003E+00 GM=-1.264E-15 RPI= 1.713E+1
 330 RO= 5.002E+13 CPI= 4.500E-13 CMU= 4.235E-13 BETAAC=-2.165E-0

331 FT=-2.304E-04

332

333 NAME: Q46 MODEL: RNO

334

335 IB=-6.225E-12	IC= 6.245E-12	VBE= 0.000E+00	VBC= 1.026E+0
336 VCE= 1.026E+00	BFTADC=-1.003E+00	GM=-1.264E-15	RPI= 1.713E+0
337 RO= 5.002E+13	CPI= 4.500E-13	CMU= 4.235E-13	BETAAC=-2.165E+0
338 FT=-2.304E-04			

339

340 NAME: Q47 MODEL: RPO

341

342 IB=-1.215E-06	IC=-1.879E-04	VBE=-6.903E-01	VBC= 1.282E+0
343 VCE=-1.351E+01	BFTADC= 1.546E+02	GM= 7.256E-03	RPI= 2.245E+0
344 RO= 3.752E+05	CPI= 2.977E-12	CMU= 1.824E-13	BETAAC= 1.629E+0
345 FT= 3.655E+08			

346

347 NAME: Q48 MODEL: RPO

348

349 IB=-1.216E-06	IC=-1.879E-04	VBE=-6.903E-01	VBC= 1.281E+0
350 VCE=-1.350E+01	BFTADC= 1.545E+02	GM= 7.256E-03	RPI= 2.245E+0
351 RO= 3.750E+05	CPI= 2.978E-12	CMU= 1.825E-13	BETAAC= 1.629E+0
352 FT= 3.654E+08			

353

354 NAME: Q49 MODEL: RNO

355

356 IB= 3.124E-07	IC= 5.063E-05	VBE= 6.479E-01	VBC=-1.281E+0
357 VCE= 1.345E+01	BFTADC= 1.621E+02	GM= 1.964E-03	RPI= 9.597E+0
358 RO= 1.685E+06	CPI= 9.412E-13	CMU= 2.680E-13	BETAAC= 1.885E+0
359 FT= 2.586E+08			

360

361 NAME: Q50 MODEL: RN1

362

363 IB= 1.231E-06	IC= 1.876E-04	VBE= 6.681E-01	VBC=-6.303E+0
364 VCE= 1.298E+00	BFTADC= 1.523E+02	GM= 7.261E-03	RPI= 2.337E+0
365 RO= 3.892E+05	CPI= 2.345E-12	CMU= 6.869E-13	BETAAC= 1.697E+0
366 FT= 3.811E+08			

367

368 NAME: Q51 MODEL: RN1

369

370 IB= 1.231E-06	IC= 1.876E-04	VBE= 6.681E-01	VBC=-6.479E+0
371 VCE= 1.316E+00	BFTADC= 1.524E+02	GM= 7.261E-03	RPI= 2.338E+0
372 RO= 3.892E+05	CPI= 2.345E-12	CMU= 6.843E-13	BETAAC= 1.697E+0
373 FT= 3.815E+08			

374

375 NAME: Q52 MODEL: RN1

376

377 IB= 2.191E-07	IC= 2.424E-05	VBE= 6.151E-01	VBC=-4.027E+0
378 VCE= 1.018E+00	BFTADC= 1.106E+02	GM= 9.415E-04	RPI= 1.496E+0
379 RO= 3.015E+06	CPI= 1.377E-12	CMU= 7.054E-13	BETAAC= 1.408E+0
380 FT= 7.194E+07			

381

382 NAME: Q53 MODEL: RN1

383

384 IB= 2.191E-07	IC= 2.424E-05	VBE= 6.151E-01	VBC=-4.027E+0
385 VCE= 1.018E+00	BFTADC= 1.106E+02	GM= 9.415E-04	RPI= 1.496E+0

386 $RO = 3.015E+06$ $CPI = 1.377E-12$ $CMII = 7.054E-13$ $BETAAC = 1.408E+0$
 387 $FT = 7.194E+07$
 388
 389 NAME: Q54 MODEL: RP0
 390
 391 $IB = -2.386E-06$ $IC = -3.742E-04$ $VBE = -7.089E-01$ $VBC = 1.287E+0$
 392 $VCE = -1.358E+01$ $BETADC = 1.545E+02$ $GM = 1.451E-02$ $RPI = 1.125E+0$
 393 $RO = 1.856E+05$ $CPI = 5.253E-12$ $CMII = 1.835E-13$ $BETAAC = 1.633E+0$
 394 $FT = -6.249E+08$
 395
 396 NAME: Q55 MODEL: RP1
 397
 398 $IB = -2.581E-06$ $IC = -3.308E-04$ $VBE = -6.922E-01$ $VBC = 6.510E+0$
 399 $VCE = -1.343E+00$ $BETADC = 1.281E+02$ $GM = 1.276E-02$ $RPI = 1.055E+0$
 400 $RO = 1.761E+05$ $CPI = 6.109E-12$ $CMII = 6.984E-13$ $BETAAC = 1.347E+0$
 401 $FT = 2.944E+08$
 402
 403 NAME: Q56 MODEL: RP1
 404
 405 $IB = -6.019E-07$ $IC = -8.318E-05$ $VBE = -6.510E-01$ $VBC = 1.310E+0$
 406 $VCE = -1.375E+01$ $BETADC = 1.382E+02$ $GM = 3.228E-03$ $RPI = 4.799E+0$
 407 $RO = 8.544E+05$ $CPI = 2.358E-12$ $CMII = 2.585E-13$ $BETAAC = 1.449E+0$
 408 $FT = 1.964E+08$
 409
 410 NAME: Q57 MODEL: RN0
 411
 412 $IB = 1.589E-06$ $IC = 3.314E-04$ $VBE = 6.950E-01$ $VBC = -1.980E+0$
 413 $VCE = 2.049E+01$ $BETADC = 2.085E+02$ $GM = 1.274E-02$ $RPI = 1.738E+0$
 414 $RO = 2.772E+05$ $CPI = 2.213E-12$ $CMII = 2.459E-13$ $BETAAC = 2.215E+0$
 415 $FT = 8.250E+08$
 416
 417 NAME: Q58 MODEL: RN0
 418
 419 $IB = 2.991E-07$ $IC = 4.814E-05$ $VBE = 6.466E-01$ $VBC = -1.282E+0$
 420 $VCE = 1.347E+01$ $BETADC = 1.609E+02$ $GM = 1.868E-03$ $RPI = 1.005E+0$
 421 $RO = 1.773E+06$ $CPI = 9.285E-13$ $CMII = 2.679E-13$ $BETAAC = 1.878E+0$
 422 $FT = 2.445E+08$
 423
 424 NAME: Q59 MODEL: RN1
 425
 426 $IB = 3.722E-07$ $IC = 4.678E-05$ $VBF = 6.321E-01$ $VAC = -3.865E+0$
 427 $VCE = 1.019E+00$ $BETADC = 1.257E+02$ $GM = 1.816E-03$ $RPI = 8.385E+0$
 428 $RO = 1.560E+06$ $CPI = 1.520E-12$ $CMII = 7.110E-13$ $BETAAC = 1.523E+0$
 429 $FT = 1.296E+08$
 430
 431 NAME: Q60 MODEL: RN1
 432
 433 $IB = 2.076E-06$ $IC = 3.325E-04$ $VHF = 6.832E-01$ $VBC = -6.368E+0$
 434 $VCE = 1.320E+00$ $BETADC = 1.602E+02$ $GM = 1.283E-02$ $RPI = 1.353E+0$
 435 $RO = 2.191E+05$ $CPI = 3.193E-12$ $CMII = 7.017E-13$ $BETAAC = 1.736E+0$
 436 $FT = 5.258E+08$
 437
 438 NAME: Q61 MODEL: RP0
 439
 440 $IB = -1.923E-06$ $IC = -3.039E-04$ $VBF = -7.029E-01$ $VBC = 1.307E+0$

441 VCE=-1.377E+01 BETADC= 1.581E+02 GM= 1.169E-02 RPI= 1.402E+0
 442 RO= 2.321E+05 CPI= 4.348E-12 CMU= 1.821E-13 BETAAC= 1.640E+0
 443 FT= 4.107E+08
 444
 445 NAME: Q62 MODEL: RN1LC
 446
 447 IB= 1.883E-06 IC= 2.970E-04 VBE= 6.804E-01 VBC= 0.000E+0
 448 VCE= 6.804E-01 BETADC= 1.577E+02 GM= 1.147E-02 RPI= 1.497E+0
 449 RO= 2.435E+05 CPI= 2.991E-12 CMU= 8.508E-13 BETAAC= 1.717E+0
 450 FT= 4.752E+08
 451
 452 NAME: Q63 MODEL: RP1LC
 453
 454 IB=-2.345E-06 IC=-2.966E-04 VBE=-6.895E-01 VBC= 0.000E+0
 455 VCE=-6.895E-01 BETADC= 1.265E+02 GM= 1.145E-02 RPI= 1.165E+0
 456 RO= 1.949E+05 CPI= 5.653E-12 CMU= 1.031E-12 BETAAC= 1.334E+0
 457 FT= 2.727E+08
 458
 459 NAME: Q64 MODEL: RN1
 460
 461 IB= 4.329E-07 IC= 6.599E-05 VBE= 6.368E-01 VBC=-1.322E+0
 462 VCE= 1.386E+01 BETADC= 1.525E+02 GM= 2.562E-03 RPI= 7.119E+0
 463 RO= 1.300E+06 CPI= 1.577E-12 CMU= 3.944E-13 BETAAC= 1.824E+0
 464 FT= 2.069E+08
 465
 466 NAME: Q65 MODEL: RN1
 467
 468 IB= 1.662E-06 IC= 3.046E-04 VBE= 6.768E-01 VBC=-1.278E+0
 469 VCE= 1.346E+01 BETADC= 1.833E+02 GM= 1.178E-02 RPI= 1.705E+0
 470 RO= 2.792E+05 CPI= 2.771E-12 CMU= 3.981E-13 BETAAC= 2.008E+0
 471 FT= 5.914E+08
 472
 473 NAME: Q66 MODEL: RN1LC
 474
 475 IB= 1.926E-06 IC= 3.044E-04 VBE= 6.810E-01 VBC= 0.000E+0
 476 VCE= 6.810E-01 BETADC= 1.580E+02 GM= 1.175E-02 RPI= 1.462E+0
 477 RO= 2.376E+05 CPI= 3.033E-12 CMU= 8.523E-13 BETAAC= 1.718E+0
 478 FT= 4.814E+08
 479
 480 NAME: Q67 MODEL: RN8C
 481
 482 IB= 4.970E-06 IC= 8.145E-04 VBE= 6.481E-01 VBC=-1.428E+0
 483 VCE= 1.493E+01 BETADC= 1.647E+02 GM= 3.176E-02 RPI= 6.034E+0
 484 RO= 1.060E+05 CPI= 1.348E-11 CMU= 1.845E-12 BETAAC= 1.916E+0
 485 FT= 3.298E+08
 486
 487 NAME: Q68 MODEL: PP8C
 488
 489 IB=-5.708E-06 IC=-8.178E-04 VBE=-6.560E-01 VBC= 1.427E+0
 490 VCE=-1.493E+01 BETADC= 1.433E+02 GM= 3.173E-02 RPI= 5.014E+0
 491 RO= 8.829E+04 CPI= 2.006E-11 CMU= 1.170E-12 BETAAC= 1.591E+0
 492 FT= 2.379E+08
 493
 494 NAME: Q69 MODEL: RN1LC
 495

496 $IR = 1.240E-06$ $IC = 1.876E-04$ $VBE = 6.683E-01$ $VBC = 0.000E+0$
 497 $VCE = 6.683E-01$ $BETAADC = 1.513E+02$ $GM = 7.260E-03$ $RPI = 2.320E+0$
 498 $RO = 3.861E+05$ $CPI = 2.354E-12$ $CMII = 8.299E-13$ $BETAAC = 1.684E+0$
 499 $FT = 3.629E+08$
 500
 501 NAME: Q70 MODEL: RN1LC
 502
 503 $IB = 1.240E-06$ $IC = 1.876E-04$ $VBE = 6.683E-01$ $VBC = 0.000E+0$
 504 $VCE = 6.683E-01$ $BETAADC = 1.513E+02$ $GM = 7.260E-03$ $RPI = 2.320E+0$
 505 $RO = 3.861E+05$ $CPI = 2.354E-12$ $CMII = 8.299E-13$ $BETAAC = 1.684E+0$
 506 $FT = 3.629E+08$
 507
 508 NAME: Q71 MODEL: RN1LC
 509
 510 $IB = 4.795E-07$ $IC = 6.306E-05$ $VBE = 6.399E-01$ $VBC = 0.000E+0$
 511 $VCE = 6.399E-01$ $BETAADC = 1.315E+02$ $GM = 2.447E-03$ $RPI = 6.377E+0$
 512 $RO = 1.151E+06$ $CPI = 1.620E-12$ $CMII = 8.094E-13$ $BETAAC = 1.561E+0$
 513 $FT = 1.603E+08$
 514
 515 NAME: Q72 MODEL: RP1LC
 516
 517 $IR = -6.676E-07$ $IC = -7.622E-05$ $VBE = -6.540E-01$ $VBC = 0.000E+0$
 518 $VCE = -6.540E-01$ $BETAADC = 1.142E+02$ $GM = 2.957E-03$ $RPI = 4.303E+0$
 519 $RO = 7.609E+05$ $CPI = 2.478E-12$ $CMII = 8.932E-13$ $BETAAC = 1.272E+0$
 520 $FT = 1.396E+08$
 521
 522 NAME: Q73 MODEL: RNO
 523
 524 $IB = -7.364E-11$ $IC = 7.392E-11$ $VBE = 0.000E+00$ $VBC = -1.213E+0$
 525 $VCE = 1.213E+01$ $BETAADC = -1.004E+00$ $GM = -1.496E-14$ $RPI = 1.713E+1$
 526 $RO = 3.882E+13$ $CPI = 4.500E-13$ $CMII = 2.707E-13$ $BETAAC = -2.562E+0$
 527 $FT = -3.303E-03$
 528
 529 NAME: Q74 MODEL: RN1
 530
 531 $IB = -1.814E-10$ $IC = 1.821E-10$ $VBE = -6.367E-04$ $VBC = -1.495E+0$
 532 $VCE = 1.494E+01$ $BETAADC = -1.004E+00$ $GM = -3.684E-14$ $RPI = 8.564E+1$
 533 $RO = 1.637E+13$ $CPI = 8.198E-13$ $CMII = 3.844E-13$ $BETAAC = -3.155E+0$
 534 $FT = -4.869E-03$
 535
 536 NAME: Q75 MODEL: RP1
 537
 538 $IB = 1.269E-10$ $IC = -1.275E-10$ $VBE = -6.367E-04$ $VBC = 1.494E+0$
 539 $VCE = -1.494E+01$ $BETAADC = -1.004E+00$ $GM = -2.629E-14$ $RPI = 1.208E+1$
 540 $RO = 2.450E+13$ $CPI = 9.502E-13$ $CMII = 2.473E-13$ $BETAAC = -3.176E+0$
 541 $FT = -3.494E-03$
 542
 543 NAME: Q76 MODEL: RP0
 544
 545 $IB = 5.065E-12$ $IC = -5.081E-12$ $VBE = 0.000E+00$ $VBC = 1.192E+0$
 546 $VCE = -1.192E+00$ $BETAADC = -1.003E+00$ $GM = -1.083E-15$ $RPI = 2.447E+1$
 547 $RO = 7.060E+13$ $CPI = 5.200E-13$ $CMII = 3.678E-13$ $BETAAC = -2.649E+0$
 548 $FT = -1.941E-04$
 549
 550 NAME: Q77 MODEL: RP1

551
 552 $IB = 1.013E-11$ $IC = 1.016E-11$ $VBE = 0.000E+00$ $VBC = 1.192E+0$
 553 $VCE = -1.192E+00$ $BETADC = -1.003E+00$ $GM = -2.166E-15$ $RPI = 1.223E+1$
 554 $RO = 3.570E+13$ $CPI = 9.500E-13$ $CMII = 5.272E-13$ $BETAAC = -2.649E-0$
 555 $FT = -2.333E-04$
 556
 557 NAME: Q78 MODEL: RP0
 558
 559 $IB = 5.065E-12$ $IC = -5.081E-12$ $VBE = 0.000E+00$ $VBC = 1.192E+0$
 560 $VCE = -1.192E+00$ $BETADC = -1.003E+00$ $GM = -1.083E-15$ $RPI = 2.447E+1$
 561 $RO = 7.060E+13$ $CPI = 5.200E-13$ $CMII = 3.678E-13$ $BETAAC = -2.649E-0$
 562 $FT = -1.941E-04$
 563
 564 NAME: Q79 MODEL: RN1
 565
 566 $IB = -1.317E-11$ $IC = 1.321E-11$ $VBE = 0.000E+00$ $VBC = -1.085E+0$
 567 $VCE = 1.085E+00$ $BETADC = -1.003E+00$ $GM = -2.674E-15$ $RPI = 8.564E+1$
 568 $RO = 2.497E+13$ $CPI = 8.200E-13$ $CMII = 6.223E-13$ $BETAAC = -2.290E-0$
 569 $FT = -2.951E-04$
 570
 571 NAME: Q80 MODEL: RN1
 572
 573 $IB = -1.317E-11$ $IC = 1.321E-11$ $VBE = 0.000E+00$ $VBC = -1.085E+0$
 574 $VCE = 1.085E+00$ $BETADC = -1.003E+00$ $GM = -2.674E-15$ $RPI = 8.564E+1$
 575 $RO = 2.497E+13$ $CPI = 8.200E-13$ $CMII = 6.223E-13$ $BETAAC = -2.290E-0$
 576 $FT = -2.951E-04$
 577
 578 NAME: Q81 MODEL: RN1
 579
 580 $IB = -1.317E-11$ $IC = 1.321E-11$ $VBE = 0.000E+00$ $VBC = -1.085E+0$
 581 $VCE = 1.085E+00$ $BETADC = -1.003E+00$ $GM = -2.674E-15$ $RPI = 8.564E+1$
 582 $RO = 2.497E+13$ $CPI = 8.200E-13$ $CMII = 6.223E-13$ $BETAAC = -2.290E-0$
 583 $FT = -2.951E-04$
 584
 585 NAME: Q82 MODEL: RN1
 586
 587 $IB = -1.317E-11$ $IC = 1.321E-11$ $VBE = 0.000E+00$ $VBC = -1.085E+0$
 588 $VCE = 1.085E+00$ $BETADC = -1.003E+00$ $GM = -2.674E-15$ $RPI = 8.564E+1$
 589 $RO = 2.497E+13$ $CPI = 8.200E-13$ $CMII = 6.223E-13$ $BETAAC = -2.290E-0$
 590 $FT = -2.951E-04$
 591
 592 NAME: Q83 MODEL: RP0
 593
 594 $IB = 6.721E-11$ $IC = -6.748E-11$ $VBF = 0.000E+00$ $VAC = 1.582E+0$
 595 $VCE = -1.582E+01$ $BETADC = -1.004E+00$ $GM = -1.437E-14$ $RPI = 2.447E+1$
 596 $RO = 4.806E+13$ $CPI = 5.200E-13$ $CMII = 1.694E-13$ $BETAAC = -3.516E-0$
 597 $FT = -3.317E-03$
 598
 599 NAME: Q84 MODEL: RN8C
 600
 601 $IB = -1.370E-10$ $IC = 1.375E-10$ $VBE = 0.000E+00$ $VHC = -1.370E+0$
 602 $VCE = 1.370E+00$ $BETADC = -1.03E+00$ $GM = -2.702E-14$ $RPI = 1.070E+1$
 603 $RO = 3.098E+12$ $CPI = 6.200E-12$ $CMII = 2.853E-12$ $BETAAC = -2.892E-0$
 604 $FT = -4.749E-04$
 605

W1

28 JUN 79

21:51:17

HARRTS SLASH/8

PAGE

606 NAME: Q85 MODEL: RNO

607

608 IR=-1.285E-11 IC= 1.289E-11 VRF= 0.000E+00 VBC=-2.118E+00
609 VCE= 2.118E+00 BETAOC=-1.003E+00 GM=-2.610E-15 RPT= 1.713E+00
610 RO= 4.864E+13 CPI= 4.500E-13 CMU= 3.774E-13 BETAAC=-4.471E-00
611 FT=-5.021E-04

3

1 D1NS PHOTOPREAMPLIFIER OPERATING POINTS (TEMPERATURE 125 DEGREES C)

2
3
4 ----- VOLTAGE SUPPLY CURRENTS -----
5

6 NAME CURRNT NAME CURRNT
7 VPOS -3.430E-03 VNFG 3.894E-03 TOTAL POWER = 110 MW (ONE CHANNEL)

8
9
10 ----- ZENER DIODE -----
11

12 NAME: DZ1 MODEL: DZR
13

14 ID=-2.774E-04 VD=-6.460E+00 PEG= 1.259E+02 CAP= 1.297E-

15
16 ----- BJT'S -----
17

18 NAME: Q1 MODEL: RP0
19

20 IB= 3.197E-08 IC=-6.922E-05 VBE=-4.873E-01 VBC= 1.294E+0
21 VCE=-1.343E+01 BETADC=-2.165E+03 GM= 1.996E-03 RPI= 1.008E+0
22 R0= 1.035E+06 CPI= 1.375E-12 CMU= 1.386E-13 BETAAC= 2.012E+0
23 FT= 2.099E+08
24

25 NAME: Q2 MODEL: RP0
26

27 IB= 3.242E-08 IC=-6.975E-05 VBE=-4.875E-01 VBC= 1.303E+0
28 VCE=-1.351E+01 BETADC=-2.151E+03 GM= 2.012E-03 RPT= 1.002E+0
29 R0= 1.028E+06 CPI= 1.379E-12 CMU= 1.383E-13 BETAAC= 2.016E+0
30 FT= 2.110E+08
31

32 NAME: Q3 MODEL: RN0
33

34 IB=-3.591E-07 IC= 5.092E-05 VBE= 4.651E-01 VBC=-1.349E+0
35 VCE= 1.395E+01 BETADC=-1.418E+02 GM= 1.460E-03 RPI= 1.569E+0
36 R0= 1.717E+06 CPI= 8.572E-13 CMU= 2.371E-13 BETAAC= 2.291E+0
37 FT= 2.124E+08
38

39 NAME: Q4 MODEL: RN1
40

41 IB= 4.037E-07 IC= 7.014E-05 VBE= 4.586E-01 VBC=-5.488E-0
42 VCE= 1.007E+00 BETADC= 1.737E+02 GM= 2.036E-03 RPI= 9.380E+0
43 R0= 1.048E+06 CPI= 1.521E-12 CMU= 6.511E-13 BETAAC= 1.909E+0
44 FT= 1.492E+08
45

46 NAME: Q5 MODEL: RN1
47

48 IB= 4.118E-07 IC= 7.010E-05 VBE= 4.584E-01 VBC=-4.651E-0
49 VCE= 9.237E-01 BETADC= 1.703E+02 GM= 2.035E-03 RPI= 9.374E+0
50 R0= 1.048E+06 CPI= 1.521E-12 CMU= 6.681E-13 BETAAC= 1.907E+0
51 FT= 1.479E+08
52

53 NAME: Q6 MODEL: RN1
54

55 IB= 1.902E-07 IC= 2.487E-05 VBE= 4.230E-01 VBC=-1.075E-0

AD-A112 258

HARRIS CORP MELBOURNE FL
DIMS FINAL REPORT, (U)
OCT 79 C P HERNANDEZ, J W BOARMAN

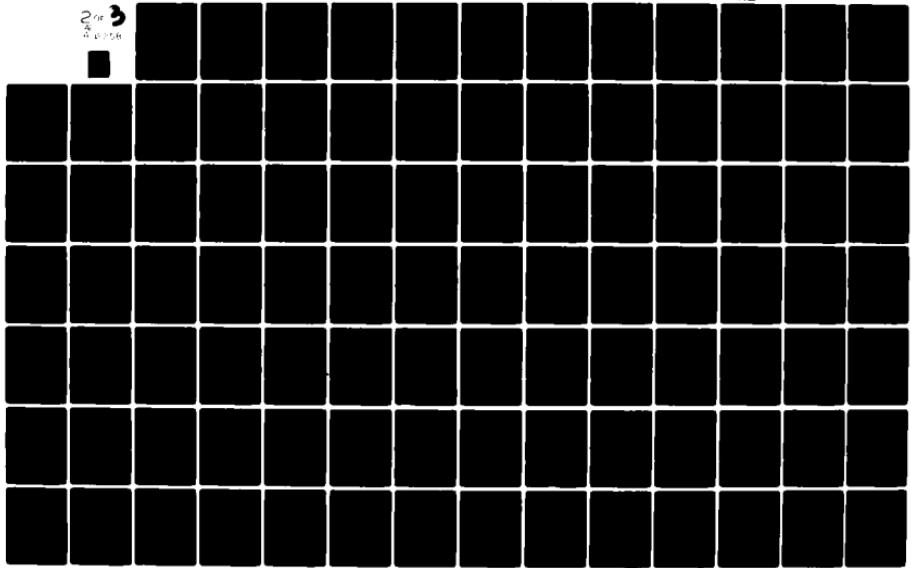
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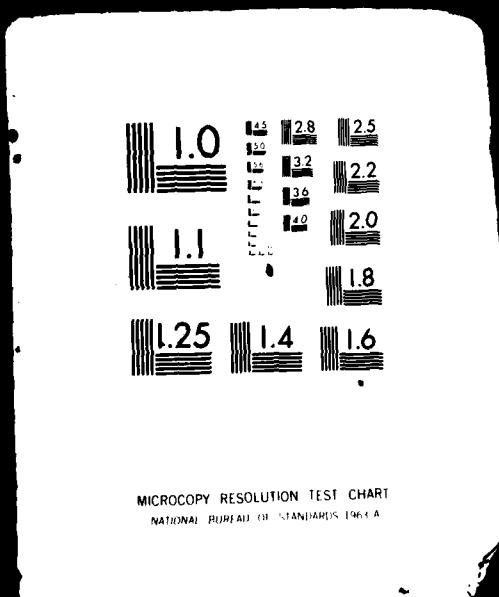
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NL

2 of 3
10-10-79



2 OF 3
AD
A/12258



56 VCE= 5.305E+01 BETADC= 1.308E+02 GM= 7.228E-04 RPI= 2.297E+
 57 RO= 2.927E+06 CPI= 1.289E-12 CMII= 7.611E-13 BETAAC= 1.660E+
 58 FT= 5.610E+07
 59
 60 NAME: Q7 MODEL: RN1
 61
 62 IB= 1.902E-07 IC= 2.487E-05 VBE= 4.230E-01 VBC=-1.075E-
 63 VCE= 5.305E+01 BETADC= 1.308E+02 GM= 7.228E-04 RPI= 2.297E+
 64 RO= 2.927E+06 CPI= 1.289E-12 CMII= 7.611E-13 BETAAC= 1.660E+
 65 FT= 5.610E+07
 66
 67 NAME: Q8 MODEL: RP0
 68
 69 IB=-2.723E-07 IC=-1.394E-04 VBE=-5.112E-01 VBC= 1.404E+
 70 VCE=-1.455E+01 BETADC= 5.120E+02 GM= 4.023E-03 RPI= 5.229E+
 71 RO= 5.185E+05 CPI= 1.983E-12 CMII= 1.355E-13 BETAAC= 2.104E+
 72 FT= 3.022E+08
 73
 74 NAME: Q9 MODEL: RP1
 75
 76 IB=-1.812E-06 IC=-2.826E-04 VBE=-5.196E-01 VBC= 4.576E-
 77 VCE=-9.772E-01 BETADC= 1.559E+02 GM= 8.172E-03 RPI= 2.097E+
 78 RO= 2.021E+05 CPI= 4.453E-12 CMII= 1.393E-12 BETAAC= 1.714E+
 79 FT= 2.225E+08
 80
 81 NAME: Q10 MODEL: RP1
 82
 83 IB= 5.154E-07 IC=-5.986E-05 VBE=-4.576E-01 VBC= 1.361E+
 84 VCE=-1.407E+01 BETADC=-1.162E+02 GM= 1.713E-03 RPI= 1.116E+
 85 RO= 1.218E+06 CPI= 1.895E-12 CMII= 1.954E-13 BETAAC= 1.912E+
 86 FT= 1.304E+08
 87
 88 NAME: Q11 MODEL: RN0
 89
 90 IB= 1.894E-07 IC= 2.821E-04 VBE= 5.222E-01 VBC=-2.056E+
 91 VCE= 2.109E+01 BETADC= 1.489E+03 GM= 8.107E-03 RPI= 3.375E+
 92 RO= 3.306E+05 CPI= 1.651E-12 CMII= 2.183E-13 BETAAC= 2.736E+
 93 FT= 6.903E+08
 94
 95 NAME: Q12 MODEL: RN0
 96
 97 IB=-3.695E-07 IC= 4.752E-05 VBF= 4.628E-01 VBC=-1.340E+
 98 VCE= 1.387E+01 BETADC=-1.298E+02 GM= 1.364E-03 RPI= 1.666E+
 99 RO= 1.635E+06 CPI= 8.440E-13 CMII= 2.374E-13 BETAAC= 2.274E+
 100 FT= 2.008E+08
 101
 102 NAME: Q13 MODEL: RN1
 103
 104 IB= 3.133E-07 IC= 4.733E-05 VBF= 4.452E-01 VBC=-1.934E-0
 105 VCE= 6.386E+01 BETADC= 1.511E+02 GM= 1.375E-03 RPI= 1.323E+0
 106 RO= 1.545E+06 CPI= 1.410E-12 CMII= 7.377E-13 BETAAC= 1.818E+0
 107 FT= 1.019E+08
 108
 109 NAME: Q14 MODEL: RN1
 110

111 IB= 1.487E-06 IC= 2.832E-04 VBE= 5.073E-01 VBC= -4.459E-
 112 VCE= 9.532E-01 BETADC= 1.905E+02 GM= 8.189E-03 RPI= 2.579E+
 113 RO= 2.581E+05 CPI= 2.480E-12 CMII= 7.698E-13 BETAAC= 2.112E+
 114 FT= 4.010E+08
 115
 116 NAME: Q15 MODEL: RP0
 117
 118 IB=-8.020E-07 IC=-2.439E-04 VBE=-5.312E-01 VBC= 1.357E+
 119 VCE=-1.410E+01 BETADC= 3.042E+02 GM= 7.026E-03 RPI= 3.008E+
 120 RO= 2.926E+05 CPI= 2.920E-12 CMU= 1.381E-13 BETAAC= 2.114E+
 121 FT= 3.657E+08
 122
 123 NAME: Q16 MODEL: RN1LC
 124
 125 IB= 1.554E-06 IC= 2.445E-04 VBE= 5.024E-01 VBC= 0.000E+0
 126 VCE= 5.024E-01 BETADC= 1.574E+02 GM= 7.042E-03 RPI= 2.950E+0
 127 RO= 2.289E+05 CPI= 2.315E-12 CMU= 1.132E-12 BETAAC= 2.089E+0
 128 FT= 3.270E+08
 129
 130 NAME: Q17 MODEL: PP1LC
 131
 132 IB=-1.988E-06 IC=-2.441E-04 VBE=-5.147E-01 VBC= 0.000E+0
 133 VCE=-5.147E-01 BETADC= 1.227E+02 GM= 7.074E-03 RPI= 2.407E+0
 134 RO= 1.441E+05 CPI= 4.047E-12 CMU= 3.323E-12 BETAAC= 1.702E+0
 135 FT= 1.528E+08
 136
 137 NAME: Q18 MODEL: RN1
 138
 139 IB=-9.236E-07 IC= 5.929E-05 VBE= 4.459E-01 VBC= -1.361E+0
 140 VCE= 1.406E+01 BETADC= -6.420E+01 GM= 1.685E-03 RPI= 1.282E+0
 141 RO= 1.488E+06 CPI= 1.419E-12 CMII= 3.506E-13 BETAAC= 2.160E+0
 142 FT= 1.516E+08
 143
 144 NAME: Q19 MODEL: RN1
 145
 146 IB=-7.990E-08 IC= 2.452E-04 VBE= 4.959E-01 VBC= -1.335E+0
 147 VCE= 1.385E+01 BETADC= -3.069E+03 GM= 7.068E-03 RPI= 3.459E+0
 148 RO= 3.526E+05 CPI= 2.146E-12 CMU= 3.534E-13 BETAAC= 2.445E+0
 149 FT= 4.501E+08
 150
 151 NAME: Q20 MODEL: RN1LC
 152
 153 IB= 1.546E-06 IC= 2.436E-04 VBE= 5.023E-01 VBC= 0.000E+0
 154 VCE= 5.023E-01 BETADC= 1.576E+02 GM= 7.056E-03 RPI= 2.960E+0
 155 RO= 2.307E+05 CPI= 2.311E-12 CMU= 1.128E-12 BETAAC= 2.089E+0
 156 FT= 3.265E+08
 157
 158 NAME: Q21 MODEL: PN4
 159
 160 IB=-2.505E-06 IC= 5.758E-04 VBE= 4.765E-01 VBC= -1.446E+0
 161 VCE= 1.494E+01 BETADC= -2.299E+02 GM= 1.655E-02 RPI= 1.441E+0
 162 RO= 1.530E+05 CPI= 6.886E-12 CMII= 9.974E-13 BETAAC= 2.385E+0
 163 FT= 3.341E+08
 164
 165 NAME: Q22 MODEL: RP4

166
 167 $IB = 5.746E-07$ $IC = -5.74AE-04$ $VBE = -4.879E-01$ $VBC = 1.445E+01$
 168 $VCE = -1.494E+01$ $BETAADC = -1.000E+03$ $GM = 1.657E-02$ $RPI = 1.240E+01$
 169 $RO = 1.271E+05$ $CPI = 1.039E-11$ $CMU = 5.604E-13$ $BETAAC = 2.054E+01$
 170 $FT = 2.408E+08$
 171
 172 NAME: Q23 MODEL: RN1LC
 173
 174 $IB = 4.5A0E-07$ $IC = 7.008E-05$ $VBE = 4.5A8E-01$ $VBC = 0.000E+01$
 175 $VCE = 4.5A8E-01$ $BETAADC = 1.530E+02$ $GM = 2.035E-03$ $RPI = 9.323E+01$
 176 $RO = 1.027E+06$ $CPI = 1.523E-12$ $CMU = 8.423E-13$ $BETAAC = 1.898E+01$
 177 $FT = 1.370E+08$
 178
 179 NAME: Q24 MODEL: RN1LC
 180
 181 $IB = 4.579E-07$ $IC = 7.006E-05$ $VBE = 4.5A8E-01$ $VBC = 0.000E+01$
 182 $VCE = 4.5A8E-01$ $BETAADC = 1.530E+02$ $GM = 2.035E-03$ $RPI = 9.325E+01$
 183 $RO = 1.027E+06$ $CPI = 1.523E-12$ $CMU = 8.423E-13$ $BETAAC = 1.898E+01$
 184 $FT = 1.369E+08$
 185
 186 NAME: Q25 MODEL: RN1LC
 187
 188 $IB = 3.800E-07$ $IC = 5.600E-05$ $VBE = 4.511E-01$ $VBC = 0.000E+01$
 189 $VCE = 4.511E-01$ $BETAADC = 1.474E+02$ $GM = 1.627E-03$ $RPI = 1.138E+01$
 190 $RO = 1.288E+06$ $CPI = 1.454E-12$ $CMU = 8.327E-13$ $BETAAC = 1.851E+01$
 191 $FT = 1.132E+08$
 192
 193 NAME: Q26 MODEL: RP1LC
 194
 195 $IB = -4.210E-07$ $IC = -5.592E-05$ $VBE = -4.633E-01$ $VBC = 0.000E+01$
 196 $VCE = -4.633E-01$ $BETAADC = 1.328E+02$ $GM = 1.624E-03$ $RPI = 9.683E+01$
 197 $RO = 1.035E+06$ $CPI = 1.986E-12$ $CMU = 1.009E-12$ $BETAAC = 1.573E+01$
 198 $FT = 8.632E+07$
 199
 200 NAME: Q27 MODEL: RN1LC
 201
 202 $IB = 1.809E-06$ $IC = 2.706E-04$ $VBE = 5.060E-01$ $VBC = 0.000E+01$
 203 $VCE = 5.060E-01$ $BETAADC = 1.496E+02$ $GM = 7.838E-03$ $RPI = 2.679E+01$
 204 $RO = 1.789E+05$ $CPI = 2.431E-12$ $CMU = 1.261E-12$ $BETAAC = 2.099E+01$
 205 $FT = 3.378E+08$
 206
 207 NAME: Q28 MODEL: PN1LC
 208
 209 $IB = 1.809E-06$ $IC = 2.706E-04$ $VBE = 5.060E-01$ $VBC = 0.000E+01$
 210 $VCE = 5.060E-01$ $BETAADC = 1.496E+02$ $GM = 7.838E-03$ $RPI = 2.679E+01$
 211 $RO = 1.789E+05$ $CPI = 2.431E-12$ $CMU = 1.261E-12$ $BETAAC = 2.099E+01$
 212 $FT = 3.378E+08$
 213
 214 NAME: Q29 MODEL: RN1LC
 215
 216 $IB = 1.809E-06$ $IC = 2.706E-04$ $VBE = 5.060E-01$ $VBC = 0.000E+01$
 217 $VCE = 5.060E-01$ $BETAADC = 1.496E+02$ $GM = 7.838E-03$ $RPI = 2.679E+01$
 218 $RO = 1.789E+05$ $CPI = 2.431E-12$ $CMU = 1.261E-12$ $BETAAC = 2.099E+01$
 219 $FT = 3.378E+08$
 220

221 NAME: Q30 MODEL: RNO
 222
 223 IR=-5.991E-07 IC= 6.239E-07 VBE= 0.000E+00 VBC=-1.289E+
 224 VCE= 1.289E+01 BETADC=-1.041E+00 GM=-1.322E-09 RPI= 6.762E+
 225 RO= 4.540E+08 CPI= 4.501E-13 CMU= 2.389E-13 BETAAC=-8.941E-
 226 FT=-3.054E+02
 227
 228 NAME: Q31 MODEL: RNO
 229
 230 IR=-3.687E-07 IC= 6.511E-05 VBE= 4.731E-01 VBC=-1.494E+
 231 VCE= 1.541E+01 BETADC=-1.766E+02 GM= 1.869E-03 RPI= 1.272E+
 232 RO= 1.363E+06 CPI= 9.090E-13 CMU= 2.322E-13 BETAAC= 2.378E+
 233 FT= 2.607E+08
 234
 235 NAME: Q32 MODEL: RNO
 236
 237 IR=-3.687E-07 IC= 6.511E-05 VBE= 4.731E-01 VBC=-1.494E+
 238 VCE= 1.541E+01 BETADC=-1.766E+02 GM= 1.869E-03 RPI= 1.272E+
 239 RO= 1.363E+06 CPI= 9.090E-13 CMU= 2.322E-13 BETAAC= 2.378E+
 240 FT= 2.607E+08
 241
 242 NAME: Q33 MODEL: RNO
 243
 244 IR=-3.039E-07 IC= 6.471E-05 VBE= 4.734E-01 VBC=-1.360E+
 245 VCE= 1.407E+01 BETADC=-2.130E+02 GM= 1.860E-03 RPI= 1.261E+
 246 RO= 1.349E+06 CPI= 9.115E-13 CMU= 2.368E-13 BETAAC= 2.344E+
 247 FT= 2.577E+08
 248
 249 NAME: Q34 MODEL: RNO
 250
 251 IR=-3.039E-07 IC= 6.471E-05 VBE= 4.734E-01 VBC=-1.360E+
 252 VCE= 1.407E+01 BETADC=-2.130E+02 GM= 1.860E-03 RPI= 1.261E+
 253 RO= 1.349E+06 CPI= 9.115E-13 CMU= 2.368E-13 BETAAC= 2.344E+
 254 FT= 2.577E+08
 255
 256 NAME: Q35 MODEL: RP0
 257
 258 IR= 2.870E-08 IC=-2.973E-08 VBE= 0.000E+00 VBC= 8.817E-0
 259 VCE=-8.817E-01 BETADC=-1.036E+00 GM=-6.709E-11 RPI= 9.686E+0
 260 RO= 8.466E+08 CPI= 5.200E-13 CMU= 3.181E-13 BETAAC=-6.498E-0
 261 FT=-1.274E+01
 262
 263 NAME: Q36 MODEL: RP1
 264
 265 IR= 5.740E-08 IC=-5.946E-08 VBE= 0.000E+00 VBC= 8.817E-0
 266 VCE=-8.817E-01 BETADC=-1.036E+00 GM=-1.337E-10 RPI= 4.843E+0
 267 RO= 4.273E+08 CPI= 9.500E-13 CMU= 4.563E-13 BETAAC=-6.475E-0
 268 FT=-1.513E+01
 269
 270 NAME: Q37 MODEL: RP0
 271
 272 IR= 2.870E-08 IC=-2.973E-08 VBE= 0.000E+00 VBC= 8.817E-0
 273 VCE=-8.817E-01 BETADC=-1.036E+00 GM=-6.709E-11 RPI= 9.686E+0
 274 RO= 8.466E+08 CPI= 5.200E-13 CMU= 3.181E-13 BETAAC=-6.498E-0
 275 FT=-1.274E+01

276
 277 NAME: Q38 MODEL: RN1
 278
 279 $IB=-8.086E-08$ $IC= 8.375E-08$ $VBE= 0.000E+00$ $VBC=-8.698E-0$
 280 $VCE= 8.698E-01$ $BETADC=-1.036E+00$ $GM=-1.776E-10$ $RPI= 3.393E+0$
 281 $RO= 2.981E+08$ $CPI= 8.200E-13$ $CMU= 5.916E-13$ $BETAAC=-6.025E-0$
 282 $FT=-2.002E+01$
 283
 284 NAME: Q39 MODEL: RN1
 285
 286 $IB=-8.086E-08$ $IC= 8.375E-08$ $VBE= 0.000E+00$ $VBC=-8.698E-0$
 287 $VCE= 8.698E-01$ $BETADC=-1.036E+00$ $GM=-1.776E-10$ $RPI= 3.393E+0$
 288 $RO= 2.981E+08$ $CPI= 8.200E-13$ $CMU= 5.916E-13$ $BETAAC=-6.025E-0$
 289 $FT=-2.002E+01$
 290
 291 NAME: Q40 MODEL: RN1
 292
 293 $IB=-8.086E-08$ $IC= 8.375E-08$ $VBE= 0.000E+00$ $VBC=-8.698E-0$
 294 $VCE= 8.698E-01$ $BETADC=-1.036E+00$ $GM=-1.776E-10$ $RPI= 3.393E+0$
 295 $RO= 2.981E+08$ $CPI= 8.200E-13$ $CMU= 5.916E-13$ $BETAAC=-6.025E-0$
 296 $FT=-2.002E+01$
 297
 298 NAME: Q41 MODEL: RN1
 299
 300 $IB=-8.086E-08$ $IC= 8.375E-08$ $VBE= 0.000E+00$ $VBC=-8.698E-0$
 301 $VCE= 8.698E-01$ $BETADC=-1.036E+00$ $GM=-1.776E-10$ $RPI= 3.393E+0$
 302 $RO= 2.981E+08$ $CPI= 8.200E-13$ $CMU= 5.916E-13$ $BETAAC=-6.025E-0$
 303 $FT=-2.002E+01$
 304
 305 NAME: Q42 MODEL: RP0
 306
 307 $IB= 4.869E-07$ $IC= 5.084E-07$ $VBE= 0.000E+00$ $VBC= 1.496E+0$
 308 $VCE=-1.496E+01$ $BETADC=-1.044E+00$ $GM=-1.137E-09$ $RPI= 9.663E+0$
 309 $RO= 5.816E+08$ $CPI= 5.200E-13$ $CMU= 1.316E-13$ $BETAAC=-1.098E+0$
 310 $FT=-2.776E+02$
 311
 312 NAME: Q43 MODEL: RN4
 313
 314 $IB=-3.742E-07$ $IC= 3.917E-07$ $VBE= 0.000E+00$ $VBC=-1.017E+0$
 315 $VCE= 1.017E+00$ $BETADC=-1.036E+00$ $GM=-8.146E-10$ $RPI= 8.478E+0$
 316 $RO= 7.424E+07$ $CPI= 3.200E-12$ $CMU= 1.658E-12$ $BETAAC=-6.924E-0$
 317 $FT=-2.675E+01$
 318
 319 NAME: Q44 MODEL: RN0
 320
 321 $IB=-7.094E-08$ $IC= 7.349E-08$ $VBF= 0.000E+00$ $VBC=-1.526E+0$
 322 $VCE= 1.526E+00$ $BETADC=-1.036E+00$ $GM=-1.568E-10$ $RPI= 6.797E+0$
 323 $RO= 5.862E+08$ $CPI= 4.500E-13$ $CMU= 3.629E-13$ $BETAAC=-1.064E-0$
 324 $FT=-3.070E+01$
 325
 326 NAME: Q45 MODEL: RN0
 327
 328 $IB=-4.043E-08$ $IC= 4.147E-08$ $VBE= 0.000E+00$ $VBC=-8.698E-0$
 329 $VCE= 8.698E-01$ $BETADC=-1.036E+00$ $GM=-8.937E-11$ $RPI= 6.788E+0$
 330 $RO= 5.962E+08$ $CPI= 4.500E-13$ $CMU= 3.993E-13$ $BETAAC=-6.067E-0$

331 FT=-1.675E+01
 332
 333 NAME: Q46 MODEL: RNO
 334
 335 IB=-4.043E-08 IC= 4.187E-08 VBE= 0.000E+00 VBC=-8.69AF-
 336 VCE= 8.698E-01 BETAADC=-1.036E+00 GM=-8.937E-11 RPI= 6.788E+
 337 RO= 5.962E+08 CPI= 4.500E-13 CMU= 3.993E-13 BETAAC=-6.067E-
 338 FT=-1.675E+01
 339
 340 NAME: Q47 MODEL: RPO
 341
 342 IB=-5.235E-07 IC=-1.846E-04 VBE=-5.214E-01 VBC= 1.334E+
 343 VCE=-1.396E+01 BETAADC= 3.527E+02 GM= 5.325E-03 RPI= 3.941E+
 344 RO= 3.866E+05 CPI= 2.397E-12 CMU= 1.383E-13 BETAAC= 2.099E+
 345 FT= 3.342E+08
 346
 347 NAME: Q48 MODEL: RPO
 348
 349 IB=-5.269E-07 IC=-1.852E-04 VBE=-5.216E-01 VBC= 1.332E+
 350 VCE=-1.384E+01 BETAADC= 3.515E+02 GM= 5.342E-03 RPI= 3.929E+
 351 RO= 3.853E+05 CPI= 2.403E-12 CMU= 1.384E-13 BETAAC= 2.099E+
 352 FT= 3.345E+08
 353
 354 NAME: Q49 MODEL: RNO
 355
 356 IB=-3.463E-07 IC= 5.199E-05 VBE= 4.659E-01 VBC=-1.332E+
 357 VCE= 1.379E+01 BETAADC=-1.501E+02 GM= 1.491E-03 RPI= 1.537E+
 358 RO= 1.678E+06 CPI= 8.618E-13 CMU= 2.377E-13 BETAAC= 2.291E+
 359 FT= 2.158E+08
 360
 361 NAME: Q50 MODEL: RN1
 362
 363 IB= 1.005E-06 IC= 1.855E-04 VBE= 4.924E-01 VBC=-4.520E-
 364 VCE= 9.444E-01 BETAADC= 1.846E+02 GM= 5.375E-03 RPI= 3.844E+
 365 RO= 3.949E+05 CPI= 2.047E-12 CMU= 7.138E-13 BETAAC= 2.066E+
 366 FT= 3.098E+08
 367
 368 NAME: Q51 MODEL: RN1
 369
 370 IB= 1.004E-06 IC= 1.855E-04 VBE= 4.924E-01 VBC=-4.659E-
 371 VCE= 9.583E-01 BETAADC= 1.849E+02 GM= 5.375E-03 RPI= 3.845E+
 372 RO= 3.950E+05 CPI= 2.047E-12 CMU= 7.094E-13 BETAAC= 2.066E+
 373 FT= 3.103E+08
 374
 375 NAME: Q52 MODEL: RN1
 376
 377 IB= 1.799E-07 IC= 2.482E-05 VBE= 4.229E-01 VBC=-2.114E-
 378 VCE= 6.342E-01 BETAADC= 1.380E+02 GM= 7.208E-04 RPI= 2.305E+
 379 RO= 2.939E+06 CPI= 1.289E-12 CMU= 7.200E-13 BETAAC= 1.661E+
 380 FT= 5.711E+07
 381
 382 NAME: Q53 MODEL: RN1
 383
 384 IB= 1.799E-07 IC= 2.482E-05 VBE= 4.229E-01 VBC=-2.114E-
 385 VCE= 6.342E-01 BETAADC= 1.380E+02 GM= 7.208E-04 RPI= 2.305E+

386 $RO = 2.939E+06$ $CPI = 1.249E-12$ $CMII = 7.200E-13$ $BETAAC = 1.661E+0$
 387 $FT = 5.711E+07$

388
 389 NAME: Q54 MODEL: RP0
 390

391 $IB = -1.447E-06$	IC = $-3.714E-04$	VBE = $-5.464E-01$	VBC = $1.317E+0$
392 $VCE = -1.372E+01$	BETADC = $2.547E+02$	GM = $1.046E-02$	RPI = $1.971E+0$
393 $RO = 1.899E+05$	CPI = $4.084E-12$	CMU = $1.404E-13$	BETAAC = $2.101E+0$
394 $FT = 4.015E+08$			

395
 396 NAME: Q55 MODEL: RP1
 397

398 $IB = -2.255E-06$	IC = $-3.270E-04$	VBE = $-5.248E-01$	VBC = $4.690E+0$
399 $VCE = -9.939E-01$	BETADC = $1.450E+02$	GM = $9.451E-03$	RPI = $1.818E+0$
400 $RO = 1.499E+05$	CPI = $4.938E-12$	CMU = $2.275E-12$	BETAAC = $1.718E+0$
401 $FT = 2.085E+08$			

402
 403 NAME: Q56 MODEL: RP1
 404

405 $IB = 3.809E-07$	IC = $-8.266E-05$	VBE = $-4.690E-01$	VBC = $1.342E+0$
406 $VCE = -1.389E+01$	BETADC = $-2.170E+02$	GM = $2.375E-03$	RPI = $8.241E+0$
407 $RO = 8.761E+05$	CPI = $2.106E-12$	CMU = $1.945E-13$	BETAAC = $1.958E+0$
408 $FT = 1.642E+08$			

409
 410 NAME: Q57 MODEL: RN0
 411

412 $IB = 3.686E-07$	IC = $3.266E-04$	VBE = $5.275E-01$	VBC = $-2.037E+0$
413 $VCE = 2.090E+01$	BETADC = $8.861E+02$	GM = $9.377E-03$	RPI = $2.922E+0$
414 $RO = 2.845E+05$	CPI = $1.807E-12$	CMU = $2.190E-13$	BETAAC = $2.740E+0$
415 $FT = 7.365E+08$			

416
 417 NAME: Q58 MODEL: RN0
 418

419 $IB = -3.648E-07$	IC = $4.803E-05$	VBE = $4.631E-01$	VBC = $-1.334E+0$
420 $VCE = 1.380E+01$	BETADC = $-1.317E+02$	GM = $1.376E-03$	RPI = $1.652E+0$
421 $RO = 1.818E+06$	CPI = $8.458E-13$	CMU = $2.376E-13$	BETAAC = $2.274E+0$
422 $FT = 2.022E+08$			

423
 424 NAME: Q59 MODEL: RN1
 425

426 $IB = 3.134E-07$	IC = $4.748E-05$	VBE = $4.453E-01$	VBC = $-2.002E+0$
427 $VCE = 6.455E-01$	BETADC = $1.515E+02$	GM = $1.379E-03$	RPI = $1.319E+0$
428 $RO = 1.540E+06$	CPI = $1.411E-12$	CMU = $7.352E-13$	BETAAC = $1.819E+0$
429 $FT = 1.023E+08$			

430
 431 NAME: Q60 MODEL: RN1
 432

433 $IB = 1.704E-06$	IC = $3.278E-04$	VBE = $5.125E-01$	VBC = $-4.507E+0$
434 $VCE = 9.631E-01$	BETADC = $1.924E+02$	GM = $9.471E-03$	RPI = $2.243E+0$
435 $RO = 2.227E+05$	CPI = $2.677E-12$	CMU = $8.015E-13$	BETAAC = $2.124E+0$
436 $FT = 4.333E+08$			

437
 438 NAME: Q61 MODEL: RP0
 439

440 $IB = -1.076E-06$	IC = $-2.995E-04$	VBE = $-5.385E-01$	VBC = $1.350E+0$
-----------------------	-------------------	--------------------	------------------

441 VCF=-1.404E+01 BETADC= 2.784E+02 GM= 8.614E-03 RPI= 2.454E+01
 442 RO= 2.374E+05 CPI= 3.420E-12 CMU= 1.389E-13 BETAAC= 2.114E+01
 443 FT= 3.853E+08

444
 445 NAME: Q62 MODEL: RN1LC
 446
 447 IB= 2.218E-06 IC= 3.026E-04 VBE= 5.101E-01 VRC= 0.000E+00
 448 VCE= 5.101E-01 BETADC= 1.364E+02 GM= 8.764E-03 RPI= 2.407E+01
 449 RO= 1.231E+05 CPI= 2.574E-12 CMU= 1.540E-12 BETAAC= 2.110E+01
 450 FT= 3.391E+08

451
 452 NAME: Q63 MODEL: RP1LC
 453
 454 IB=-3.300E-06 IC=-3.016E-04 VBF=-5.226E-01 VRC= 0.000E+00
 455 VCE=-5.276E-01 BETADC= 9.138E+01 GM= 8.755E-03 RPI= 1.953E+01
 456 RO= 5.066E+04 CPI= 4.687E-12 CMU= 9.766E-12 BETAAC= 1.709E+01
 457 FT= 9.641E+07

458
 459 NAME: Q64 MODEL: RN1
 460
 461 IB=-8.774E-07 IC= 6.777E-05 VBE= 4.507E-01 VBC=-1.355E+00
 462 VCE= 1.400E+01 BETADC=-7.724E+01 GM= 1.932E-03 RPI= 1.136E+01
 463 RO= 1.298E+06 CPI= 1.455E-12 CMU= 3.510E-13 BETAAC= 2.194E+01
 464 FT= 1.702E+08

465
 466 NAME: Q65 MODEL: RN1
 467
 468 IB= 1.839E-07 IC= 3.028E-04 VBE= 5.035E-01 VBC=-1.315E+00
 469 VCE= 1.366E+01 BETADC= 1.646E+03 GM= 8.728E-03 RPI= 2.826E+00
 470 RO= 2.843E+05 CPI= 2.365E-12 CMU= 3.550E-13 BETAAC= 2.467E+00
 471 FT= 5.107E+08

472
 473 NAME: Q66 MODEL: RN1LC
 474
 475 IB= 2.191E-06 IC= 3.008E-04 VBE= 5.099E-01 VRC= 0.000E+00
 476 VCE= 5.099E-01 BETADC= 1.373E+02 GM= 8.712E-03 RPI= 2.421E+00
 477 RO= 1.260E+05 CPI= 2.566E-12 CMU= 1.519E-12 BETAAC= 2.109E+00
 478 FT= 3.394E+08

479
 480 NAME: Q67 MODEL: RNAC
 481
 482 IB=-6.122E-06 IC= 9.170E-04 VBE= 4.682E-01 VBC=-1.456E+00
 483 VCE= 1.503E+01 BETADC=-1.498E+02 GM= 2.630E-02 RPI= 8.902E+00
 484 RO= 9.643E+04 CPI= 1.256E-11 CMU= 1.645E-12 BETAAC= 2.342E+00
 485 FT= 2.947E+08

486
 487 NAME: Q68 MODEL: RPBC
 488
 489 IB= 2.221E-06 IC=-9.224E-04 VBE=-4.802E-01 VBC= 1.430E+00
 490 VCE=-1.478E+01 BETADC=-4.152E+02 GM= 2.656E-02 RPI= 7.625E+00
 491 RO= 7.925E+04 CPI= 1.865E-11 CMU= 8.999E-13 BETAAC= 2.025E+00
 492 FT= 2.163E+08

493
 494 NAME: Q69 MODEL: RN1LC
 495

496 IB= 1.116E-06 IC= 1.854E-04 VBE= 4.926E-01 VBC= 0.000E+0
497 VCE= 4.926E-01 BETADC= 1.661E+02 GM= 5.374E-03 RPI= 3.827E+0
498 RO= 3.580E+05 CPI= 2.051E-12 CMU= 9.754E-13 BETAAC= 2.057E+0
499 FT= 2.826E+08
500
501 NAME: Q70 MODEL: RN1LC
502
503 IB= 1.117E-06 IC= 1.854E-04 VBE= 4.926E-01 VBC= 0.000E+0
504 VCE= 4.926E-01 BETADC= 1.661E+02 GM= 5.375E-03 RPI= 3.827E+0
505 RO= 3.580E+05 CPI= 2.051E-12 CMU= 9.754E-13 BETAAC= 2.057E+0
506 FT= 2.826E+08
507
508 NAME: Q71 MODEL: RN1LC
509
510 IB= 4.230E-07 IC= 6.374E-05 VBE= 4.555E-01 VBC= 0.000E+0
511 VCE= 4.555E-01 BETADC= 1.507E+02 GM= 1.851E-03 RPI= 1.015E+0
512 RO= 1.130E+06 CPI= 1.492E-12 CMU= 8.379E-13 BETAAC= 1.878E+0
513 FT= 1.265E+08
514
515 NAME: Q72 MODEL: RP1LC
516
517 IB=-5.574E-07 IC=-7.680E-05 VBE=-4.742E-01 VBC= 0.000E+0
518 VCE=-4.742E-01 BETADC= 1.378E+02 GM= 2.230E-03 RPI= 7.220E+0
519 RO= 7.496E+05 CPI= 2.219E-12 CMU= 1.100E-12 BETAAC= 1.610E+0
520 FT= 1.069E+08
521
522 NAME: Q73 MODEL: RNO
523
524 IB=-5.849E-07 IC= 6.142E-07 VBE= 0.000E+00 VBC=-1.269E+0
525 VCE= 1.269E+01 BETADC=-1.041E+00 GM=-1.302E-09 RPI= 6.763E+0
526 RO= 4.558E+08 CPI= 4.501E-13 CMU= 2.397E-13 BETAAC=-8.804E-0
527 FT=-3.004E+02
528
529 NAME: Q74 MODEL: RN1
530
531 IB=-1.400E-06 IC= 1.460E-06 VBE=-1.658E-05 VBC=-1.506E+0
532 VCE= 1.506E+01 BETADC=-1.042E+00 GM=-3.067E-09 RPI= 3.369E+0
533 RO= 2.176E+08 CPI= 8.202E-13 CMU= 3.429E-13 BETAAC=-1.033E+0
534 FT=-4.196E+02
535
536 NAME: Q75 MODEL: RP1
537
538 IB= 9.641E-07 IC=-1.006E-06 VBE=-1.658E-05 VBC= 1.481E+0
539 VCE=-1.481E+01 BETADC=-1.044E+00 GM=-2.240E-09 RPI= 4.822E+0
540 RO= 2.918E+08 CPI= 9.502E-13 CMU= 1.895E-13 BETAAC=-1.080E+0
541 FT=-3.127E+02
542
543 NAME: Q76 MODEL: RPO
544
545 IB= 3.414E-08 IC=-3.537E-08 VBE= 0.000E+00 VBC= 1.049E+0
546 VCE=-1.049E+00 BETADC=-1.036E+00 GM=-7.980E-11 RPI= 9.686E+0
547 RO= 8.421E+08 CPI= 5.200E-13 CMU= 3.028E-13 BETAAC=-7.729E-0
548 FT=-1.544E+01
549
550 NAME: Q77 MODEL: RP1

551
 552 $IB = 6.828E-08$ $IC = -7.073E-08$ $VBE = 0.000E+00$ $VBC = 1.049E+0$
 553 $VCE = -1.049E+00$ $BETADC = -1.036E+00$ $GM = -1.590E-10$ $RPI = 4.842E+0$
 554 $RO = 4.210E+08$ $CPI = 9.500E-13$ $CMU = 4.343E-13$ $BETAAC = -7.701E-0$
 555 $FT = -1.828E+01$
 556
 557 NAME: Q78 MODEL: RP0
 558
 559 $IB = 3.414E-08$ $IC = -3.537E-08$ $VBE = 0.000E+00$ $VBC = 1.049E+0$
 560 $VCE = -1.049E+00$ $BETADC = -1.036E+00$ $GM = -7.980E-11$ $RPI = 9.686E+0$
 561 $RO = 8.421E+08$ $CPI = 5.200E-13$ $CMU = 3.028E-13$ $BETAAC = -7.729E-0$
 562 $FT = -1.544E+01$
 563
 564 NAME: Q79 MODEL: RN1
 565
 566 $IB = -8.665E-08$ $IC = 8.975E-08$ $VBF = 0.000E+00$ $VBC = -9.321E-0$
 567 $VCE = 9.321E-01$ $BETADC = -1.036E+00$ $GM = -1.903E-10$ $RPI = 3.393E+0$
 568 $RO = 2.976E+08$ $CPI = 8.200E-13$ $CMU = 5.850E-13$ $BETAAC = -6.457E-0$
 569 $FT = -2.155E+01$
 570
 571 NAME: Q80 MODEL: RN1
 572
 573 $IB = -8.665E-08$ $IC = 8.975E-08$ $VBE = 0.000E+00$ $VBC = -9.321E-0$
 574 $VCE = 9.321E-01$ $BETADC = -1.036E+00$ $GM = -1.903E-10$ $RPI = 3.393E+0$
 575 $RO = 2.976E+08$ $CPI = 8.200E-13$ $CMU = 5.850E-13$ $BETAAC = -6.457E-0$
 576 $FT = -2.155E+01$
 577
 578 NAME: Q81 MODEL: RN1
 579
 580 $IB = -8.665E-08$ $IC = 8.975E-08$ $VBF = 0.000E+00$ $VBC = -9.321E-0$
 581 $VCE = 9.321E-01$ $BETADC = -1.036E+00$ $GM = -1.903E-10$ $RPI = 3.393E+0$
 582 $RO = 2.976E+08$ $CPI = 8.200E-13$ $CMU = 5.850E-13$ $BETAAC = -6.457E-0$
 583 $FT = -2.155E+01$
 584
 585 NAME: Q82 MODEL: RN1
 586
 587 $IB = -8.665E-08$ $IC = 8.975E-08$ $VBE = 0.000E+00$ $VBC = -9.321E-0$
 588 $VCE = 9.321E-01$ $BETADC = -1.036E+00$ $GM = -1.903E-10$ $RPI = 3.393E+0$
 589 $RO = 2.976E+08$ $CPI = 8.200E-13$ $CMU = 5.850E-13$ $BETAAC = -6.457E-0$
 590 $FT = -2.155E+01$
 591
 592 NAME: Q83 MODEL: RP0
 593
 594 $IB = 5.095E-07$ $IC = -5.321E-07$ $VBE = 0.000E+00$ $VBC = 1.565E+0$
 595 $VCE = -1.565E+01$ $BETADC = -1.044E+00$ $GM = -1.189E-09$ $RPI = 9.661E+0$
 596 $RO = 5.728E+08$ $CPI = 5.201E-13$ $CMU = 1.296E-13$ $BETAAC = -1.149E+0$
 597 $FT = -2.914E+02$
 598
 599 NAME: Q84 MODEL: RNAC
 600
 601 $IB = -7.680E-07$ $IC = 7.955E-07$ $VBF = 0.000E+00$ $VBC = -1.033E+0$
 602 $VCE = 1.033E+00$ $BETADC = -1.036E+00$ $GM = -1.647E-09$ $RPI = 4.238E+0$
 603 $RO = 3.711E+07$ $CPI = 6.200E-12$ $CMU = 2.734E-12$ $BETAAC = -6.981E-0$
 604 $FT = -2.934E+01$
 605

606 NAME: Q85 MODEL: RNO
607
608 IR=-7.416E-08 IC= 7.683E-08 VBE= 0.000E+00 VBC=-1.595E+00
609 VCE= 1.595E+00 RFTADC=-1.036E+00 GM=-1.639E-10 RPI= 6.786E+00
610 RD= 5.852E+08 CPI= 4.500E-13 CMU= 3.600E-13 METAAC=-1.112E-01
611 FT=-3.221E+01

1 OINS PHOTOPREAMPLIFIER OPERATING POINTS (TEMPERATURE -55 DEGREES C)

2

3

4 ----- VOLTAGE SUPPLY CURRENTS -----

5 NAME CURRENT NAME CURRENT

6 VPOS -3.262E-03 VNEG 3.657E-03 TOTAL POWER = 104 MW (ONE CHANNEL)

7

8

9

10 ----- ZENER DIODE -----

11

12 NAME: DZ1 MODEL: DZR

13

14 ID=-2.294E-04 VD=-5.989E+00 REG= 1.127E-12 CAP= 1.441E-12

15

16 ----- BJT'S -----

17

18 NAME: Q1 MODEL: RPO

19

20 IB=-8.220E-07 IC=-6.591E-05 VBE=-1.100E+00 VBC= 1.049E+01

21 VCE=-1.159E+01 BETAADC= 8.018E+01 GM= 2.538E-03 RPI= 3.321E+01

22 RD= 1.019E+06 CPI= 1.679E-12 CMU= 2.181E-13 BETAACC= 8.430E+01

23 FT= 2.130E+08

24

25 NAME: Q2 MODEL: RPO

26

27 IB=-8.211E-07 IC=-6.590E-05 VBE=-1.100E+00 VBC= 1.056E+00

28 VCE=-1.166E+01 BETAADC= 8.026E+01 GM= 2.538E-03 RPI= 3.325E+01

29 RD= 1.020E+06 CPI= 1.678E-12 CMU= 2.177E-13 BETAACC= 8.438E+01

30 FT= 2.131E+08

31

32 NAME: Q3 MODEL: RNO

33

34 IB= 3.579E-07 IC= 4.744E-05 VBE= 1.032E+00 VBC= -1.166E+0

35 VCE= 1.274E+01 BETAADC= 1.325E+02 GM= 1.323E-03 RPI= 3.241E+0

36 RD= 1.741E+06 CPI= 1.066E-12 CMU= 2.895E-13 BETAACC= 1.507E+0

37 FT= 2.147E+08

38

39 NAME: Q4 MODEL: RN1

40

41 IB= 5.237E-07 IC= 6.555E-05 VBE= 1.075E+00 VBC= -1.153E+0

42 VCE= 2.229E+00 BETAADC= 1.123E+02 GM= 2.527E-03 RPI= 5.119E+0

43 RD= 1.100E+06 CPI= 1.881E-12 CMU= 6.451E-13 BETAACC= 1.294E+0

44 FT= 1.592E+08

45

46 NAME: Q5 MODEL: RV1

47

48 IB= 5.840E-07 IC= 6.554E-05 VBE= 1.076E+00 VBC= -1.032E+0

49 VCE= 2.158E+00 BETAADC= 1.122E+02 GM= 2.524E-03 RPI= 5.115E+0

50 RD= 1.099E+06 CPI= 1.881E-12 CMU= 5.507E-13 BETAACC= 1.292E+0

51 FT= 1.533E+08

52

53 NAME: Q6 MODEL: RV1

54

55 IB= 2.459E-07 IC= 2.331E-05 VBE= 1.049E+00 VBC= -7.581E+0

56 VCF= 1.808E+00 BETADC= 9.481E+01 GM= 8.994E-04 RPI= 1.299E+0
 57 RO= 3.080E+06 CPI= 1.622E-12 CMU= 6.787E-13 BETAAC= 1.169E+0
 58 FT= 6.221E+07
 59
 60 NAME: Q7 MODEL: RNI
 61
 62 IB= 2.459E-07 IC= 2.331E-05 VBE= 1.049E+00 VBC=-7.581E-0
 63 VCE= 1.808E+00 BETADC= 9.481E+01 GM= 8.994E-04 RPI= 1.299E+0
 64 RO= 3.080E+06 CPI= 1.622E-12 CMU= 6.787E-13 BETAAC= 1.169E+0
 65 FT= 6.221E+07
 66
 67 NAME: Q8 MODEL: RPO
 68
 69 IB=-1.551E-06 IC=-1.335E-04 VBE=-1.117E+00 VBC= 1.350E+0
 70 VCE=-1.462E+01 BETADC= 8.602E+01 GM= 5.129E-03 RPI= 1.734E+0
 71 RO= 5.248E+05 CPI= 2.440E-12 CMU= 2.016E-13 BETAAC= 8.895E+0
 72 FT= 3.090E+08
 73
 74 NAME: Q9 MODEL: RPI
 75
 76 IB=-3.828E-06 IC=-2.724E-04 VBE=-1.123E+00 VBC= 1.079E+0
 77 VCE=-2.202E+00 BETADC= 7.116E+01 GM= 1.045E-02 RPI= 7.002E+0
 78 RO= 2.112E+05 CPI= 5.489E-12 CMU= 6.135E-13 BETAAC= 7.320E+0
 79 FT= 2.727E+08
 80
 81 NAME: Q10 MODEL: RPI
 82
 83 IB=-7.733E-07 IC=-6.050E-05 VBE=-1.079E+00 VBC= 1.243E+0
 84 VCE=-1.351E+01 BETADC= 7.861E+01 GM= 2.345E-03 RPI= 3.614E+0
 85 RO= 1.137E+06 CPI= 2.307E-12 CMU= 2.961E-13 BETAAC= 8.473E+0
 86 FT= 1.433E+08
 87
 88 NAME: Q11 MODEL: RNO
 89
 90 IB= 1.663E-06 IC= 2.732E-04 VBE= 1.126E+00 VBC=-1.806E+0
 91 VCE= 1.919E+01 BETADC= 1.643E+02 GM= 1.045E-02 RPI= 1.658E+0
 92 RO= 3.246E+05 CPI= 2.113E-12 CMU= 2.655E-13 BETAAC= 1.733E+0
 93 FT= 6.993E+08
 94
 95 NAME: Q12 MODEL: RNO
 96
 97 IB= 3.486E-07 IC= 4.600E-05 VBE= 1.081E+00 VBC=-1.159E+0
 98 VCE= 1.267E+01 BETADC= 1.320E+02 GM= 1.773E-03 RPI= 8.475E+0
 99 RO= 1.794E+06 CPI= 1.058E-12 CMU= 2.899E-13 BETAAC= 1.502E+0
 100 FT= 2.093E+08
 101
 102 NAME: Q13 MODEL: RNI
 103
 104 IB= 4.217E-07 IC= 4.470E-05 VBE= 1.066E+00 VBC=-8.294E-0
 105 VCF= 1.896E+00 BETADC= 1.060E+02 GM= 1.774E-03 RPI= 7.247E+0
 106 RO= 1.607E+06 CPI= 1.757E-12 CMU= 6.724E-13 BETAAC= 1.249E+0
 107 FT= 1.129E+08
 108
 109 NAME: Q14 MODEL: RNI
 110

111 $IB = 2.124E-06$ $IC = 2.744E-04$ $VBE = 1.114E+00$ $VBC = -1.069E+00$
 112 $VCE = 2.143E+00$ $BETAOC = 1.292E+02$ $GM = 1.053E-02$ $RPI = 1.317E+00$
 113 $RO = 2.616E+05$ $CPI = 3.102E-12$ $CMU = 6.590E-13$ $BETAAC = 1.387E+00$
 114 $FT = 4.457E+08$
 115
 116 NAME: Q15 MODEL: RP0
 117
 118 $IB = -2.745E-06$ $IC = -2.358E-04$ $VBE = -1.133E+00$ $VBC = 1.240E+00$
 119 $VCE = -1.353E+01$ $BETAOC = 8.589E+01$ $GM = 9.030E-03$ $RPI = 9.707E+01$
 120 $RO = 2.918E+05$ $CPI = 3.698E-12$ $CMU = 2.077E-13$ $BETAAC = 8.765E+01$
 121 $FT = 3.680E+08$
 122
 123 NAME: Q16 MODEL: RN1LC
 124
 125 $IB = 1.829E-06$ $IC = 2.302E-04$ $VBE = 1.110E+00$ $VBC = 0.000E+00$
 126 $VCE = 1.110E+00$ $BETAOC = 1.259E+02$ $GM = 8.841E-03$ $RPI = 1.539E+00$
 127 $RO = 3.075E+05$ $CPI = 2.864E-12$ $CMU = 8.156E-13$ $BETAAC = 1.361E+00$
 128 $FT = 3.824E+08$
 129
 130 NAME: Q17 MODEL: RP1LC
 131
 132 $IB = -3.285E-06$ $IC = -2.287E-04$ $VBE = -1.119E+00$ $VBC = 0.000E+00$
 133 $VCE = -1.119E+00$ $BETAOC = 6.963E+01$ $GM = 8.745E-03$ $RPI = 8.182E+01$
 134 $RO = 2.474E+05$ $CPI = 4.918E-12$ $CMU = 9.015E-13$ $BETAAC = 7.188E+01$
 135 $FT = 2.402E+08$
 136
 137 NAME: Q18 MODEL: RN1
 138
 139 $IB = 4.562E-07$ $IC = 5.695E-05$ $VBE = 1.069E+00$ $VBC = -1.243E+00$
 140 $VCE = 1.350E+01$ $BETAOC = 1.248E+02$ $GM = 2.196E-03$ $RPI = 6.661E+01$
 141 $RO = 1.465E+06$ $CPI = 1.783E-12$ $CMU = 4.234E-13$ $BETAAC = 1.463E+01$
 142 $FT = 1.584E+08$
 143
 144 NAME: Q19 MODEL: RN1
 145
 146 $IB = 1.644E-06$ $IC = 2.384E-04$ $VBE = 1.107E+00$ $VBC = -1.155E+00$
 147 $VCE = 1.266E+01$ $BETAOC = 1.450E+02$ $GM = 9.163E-03$ $RPI = 1.720E+01$
 148 $RO = 3.453E+05$ $CPI = 2.716E-12$ $CMU = 4.302E-13$ $BETAAC = 1.576E+01$
 149 $FT = 4.635E+08$
 150
 151 NAME: Q20 MODEL: RN1LC
 152
 153 $IB = 1.887E-06$ $IC = 2.381E-04$ $VBE = 1.110E+00$ $VBC = 0.000E+00$
 154 $VCE = 1.110E+00$ $BETAOC = 1.262E+02$ $GM = 9.145E-03$ $RPI = 1.490E+01$
 155 $RO = 2.972E+05$ $CPI = 2.911E-12$ $CMU = 8.162E-13$ $BETAAC = 1.362E+01$
 156 $FT = 3.905E+08$
 157
 158 NAME: Q21 MODEL: RN4
 159
 160 $IB = 3.798E-06$ $IC = 5.356E-04$ $VBE = 1.091E+00$ $VBC = -1.387E+00$
 161 $VCE = 1.496E+01$ $BETAOC = 1.410E+02$ $GM = 2.063E-02$ $RPI = 7.643E+01$
 162 $RO = 1.582E+05$ $CPI = 8.515E-12$ $CMU = 1.191E-12$ $BETAAC = 1.577E+01$
 163 $FT = 3.383E+08$
 164
 165 NAME: Q22 MODEL: RP4

166
 167 $IR = -6.344E-06$ $IC = -5.347E-04$ $VBE = -1.099E+00$ $VBC = 1.346E+00$
 168 $VCE = -1.496E+01$ $BETAADC = 8.403E+01$ $GM = 2.060E-02$ $RPI = 4.293E+00$
 169 $RO = 1.318E+05$ $CPI = 1.243E-11$ $CMU = 8.324E-13$ $BETAAC = 8.843E+00$
 170 $FT = 2.472E+08$
 171
 172 NAME: Q23 MODEL: RN1LC
 173
 174 $IB = 5.918E-07$ $IC = 6.555E-05$ $VBE = 1.077E+00$ $VBC = 0.000E+00$
 175 $VCE = 1.077E+00$ $BETAADC = 1.108E+02$ $GM = 2.527E-03$ $RPI = 5.044E+00$
 176 $RO = 1.042E+06$ $CPI = 1.887E-12$ $CMU = 8.043E-13$ $BETAAC = 1.275E+00$
 177 $FT = 1.494E+08$
 178
 179 NAME: Q24 MODEL: RN1LC
 180
 181 $IB = 5.916E-07$ $IC = 6.554E-05$ $VBE = 1.077E+00$ $VBC = 0.000E+00$
 182 $VCE = 1.077E+00$ $BETAADC = 1.108E+02$ $GM = 2.526E-03$ $RPI = 5.046E+00$
 183 $RO = 1.083E+06$ $CPI = 1.887E-12$ $CMU = 8.043E-13$ $BETAAC = 1.274E+00$
 184 $FT = 1.494E+08$
 185
 186 NAME: Q25 MODEL: RN1LC
 187
 188 $IB = 4.924E-07$ $IC = 5.298E-05$ $VBE = 1.071E+00$ $VBC = 0.000E+00$
 189 $VCE = 1.071E+00$ $BETAADC = 1.076E+02$ $GM = 2.043E-03$ $RPI = 6.138E+00$
 190 $RO = 1.339E+06$ $CPI = 1.811E-12$ $CMU = 8.034E-13$ $BETAAC = 1.254E+00$
 191 $FT = 1.244E+08$
 192
 193 NAME: Q26 MODEL: RP1LC
 194
 195 $IB = -8.127E-07$ $IC = -5.263E-05$ $VBE = -1.080E+00$ $VBC = 0.000E+00$
 196 $VCE = -1.080E+00$ $BETAADC = 6.476E+01$ $GM = 2.029E-03$ $RPI = 3.433E+00$
 197 $RO = 1.078E+06$ $CPI = 2.347E-12$ $CMU = 8.689E-13$ $BETAAC = 6.965E+00$
 198 $FT = 1.004E+08$
 199
 200 NAME: Q27 MODEL: RN1LC
 201
 202 $IB = 1.810E-06$ $IC = 2.276E-04$ $VBE = 1.109E+00$ $VBC = 0.000E+00$
 203 $VCE = 1.109E+00$ $BETAADC = 1.258E+02$ $GM = 8.744E-03$ $RPI = 1.556E+00$
 204 $RO = 3.110E+05$ $CPI = 2.849E-12$ $CMU = 8.154E-13$ $BETAAC = 1.360E+00$
 205 $FT = 3.798E+08$
 206
 207 NAME: Q28 MODEL: RN1LC
 208
 209 $IB = 1.810E-06$ $IC = 2.276E-04$ $VBE = 1.109E+00$ $VBC = 0.000E+00$
 210 $VCE = 1.109E+00$ $BETAADC = 1.258E+02$ $GM = 8.744E-03$ $RPI = 1.556E+00$
 211 $RO = 3.110E+05$ $CPI = 2.849E-12$ $CMU = 8.154E-13$ $BETAAC = 1.360E+00$
 212 $FT = 3.798E+08$
 213
 214 NAME: Q29 MODEL: RN1LC
 215
 216 $IB = 1.810E-06$ $IC = 2.276E-04$ $VBE = 1.109E+00$ $VBC = 0.000E+00$
 217 $VCE = 1.109E+00$ $BETAADC = 1.258E+02$ $GM = 8.744E-03$ $RPI = 1.556E+00$
 218 $RO = 3.110E+05$ $CPI = 2.849E-12$ $CMU = 8.154E-13$ $BETAAC = 1.360E+00$
 219 $FT = 3.798E+08$
 220

221 NAME: Q30 MODEL: RNO
 222
 223 IB=-1.145E-16 IC= 1.145E-16 VBE= 0.000E+00 VBC=-1.047E+0
 224 VCF= 1.047E+01 BFTADC=-1.000E+00 GM=-7.481E-22 RPI= 7.138E+1
 225 RO= 6.930E+20 CPI= 4.500E-13 CMU= 2.956E-13 BETAAC=-5.340E-0
 226 FT=-1.597E-10
 227
 228 NAME: Q31 MODEL: RNO
 229
 230 IB= 4.245E-07 IC= 5.985E-05 VBE= 1.087E+00 VBC=-1.497E+0
 231 VCE= 1.606E+01 BFTADC= 1.410E+02 GM= 2.306E-03 RPI= 6.879E+0
 232 RO= 1.435E+06 CPI= 1.118E-12 CMU= 2.754E-13 BETAAC= 1.586E+0
 233 FT= 2.634E+08
 234
 235 NAME: Q32 MODEL: RNO
 236
 237 IB= 4.246E-07 IC= 5.985E-05 VBE= 1.087E+00 VBC=-1.497E+0
 238 VCE= 1.606E+01 BFTADC= 1.410E+02 GM= 2.306E-03 RPI= 6.879E+0
 239 RO= 1.435E+06 CPI= 1.118E-12 CMU= 2.754E-13 BETAAC= 1.586E+0
 240 FT= 2.634E+08
 241
 242 NAME: Q33 MODEL: RNO
 243
 244 IB= 4.443E-07 IC= 6.110E-05 VBE= 1.089E+00 VBC=-1.240E+0
 245 VCE= 1.349E+01 BFTADC= 1.375E+02 GM= 2.354E-03 RPI= 6.557E+0
 246 RO= 1.363E+06 CPI= 1.133E-12 CMU= 2.860E-13 BETAAC= 1.543E+0
 247 FT= 2.639E+08
 248
 249 NAME: Q34 MODEL: RNO
 250
 251 IB= 4.443E-07 IC= 6.110E-05 VBE= 1.089E+00 VBC=-1.240E+0
 252 VCE= 1.349E+01 BFTADC= 1.375E+02 GM= 2.354E-03 RPI= 6.557E+0
 253 RO= 1.363E+06 CPI= 1.133E-12 CMU= 2.860E-13 BETAAC= 1.543E+0
 254 FT= 2.639E+08
 255
 256 NAME: Q35 MODEL: RPO
 257
 258 IB= 1.115E-17 IC=-1.115E-17 VBE= 0.000E+00 VBC= 1.457E+0
 259 VCE=-1.457E+00 BFTADC=-1.000E+00 GM=-7.669E-23 RPI= 1.020E+1
 260 RO= 1.208E+21 CPI= 5.200E-13 CMU= 3.843E-13 BETAAC=-7.821E-0
 261 FT=-1.350E-11
 262
 263 NAME: Q36 MODEL: RP1
 264
 265 IB= 2.230E-17 IC=-2.230E-17 VBE= 0.000E+00 VBC= 1.457E+0
 266 VCF=-1.457E+00 BFTADC=-1.000E+00 GM=-1.534E-22 RPI= 5.099E+1
 267 RO= 6.039E+20 CPI= 9.500E-13 CMU= 5.509E-13 BETAAC=-7.821E-0
 268 FT=-1.626E-11
 269
 270 NAME: Q37 MODEL: RPO
 271
 272 IB= 1.115E-17 IC=-1.115E-17 VBE= 0.000E+00 VBC= 1.457E+0
 273 VCE=-1.457E+00 BFTADC=-1.000E+00 GM=-7.669E-23 RPI= 1.020E+1
 274 RO= 1.208E+21 CPI= 5.200E-13 CMU= 3.843E-13 BETAAC=-7.821E-0
 275 FT=-1.350E-11

276
 277 NAME: Q38 MODEL: RN1
 278
 279 IB=-3.167E-17 IC= 3.167E-17 VBE= 0.000E+00 VBC=-1.448E+0
 280 VCE= 1.448E+00 BETADC=-1.000E+00 GM=-2.069E-22 RPI= 3.569E+1
 281 RO= 4.268E+20 CPI= 8.200E-13 CMU= 6.227E-13 BETAAC=-7.384E-0
 282 FT=-2.282E-11
 283
 284 NAME: Q39 MODEL: RN1
 285
 286 IB=-3.167E-17 IC= 3.167E-17 VBE= 0.000E+00 VBC=-1.448E+0
 287 VCE= 1.448E+00 BETADC=-1.000E+00 GM=-2.069E-22 RPI= 3.569E+1
 288 RO= 4.268E+20 CPI= 8.200E-13 CMU= 6.227E-13 BETAAC=-7.384E-0
 289 FT=-2.282E-11
 290
 291 NAME: Q40 MODEL: PN1
 292
 293 IB=-3.167E-17 IC= 3.167E-17 VBE= 0.000E+00 VBC=-1.448E+0
 294 VCE= 1.448E+00 BETADC=-1.000E+00 GM=-2.069E-22 RPI= 3.569E+1
 295 RO= 4.268E+20 CPI= 8.200E-13 CMU= 6.227E-13 BETAAC=-7.384E-0
 296 FT=-2.282E-11
 297
 298 NAME: Q41 MODEL: RN1
 299
 300 IB=-3.167E-17 IC= 3.167E-17 VBE= 0.000E+00 VBC=-1.448E+0
 301 VCE= 1.448E+00 BETADC=-1.000E+00 GM=-2.069E-22 RPI= 3.569E+1
 302 RO= 4.268E+20 CPI= 8.200E-13 CMU= 6.227E-13 BETAAC=-7.384E-0
 303 FT=-2.282E-11
 304
 305 NAME: Q42 MODEL: RP0
 306
 307 IB= 1.144E-16 IC=-1.144E-16 VBE= 0.000E+00 VBC= 1.495E+0
 308 VCE=-1.495E+01 BETADC=-1.000E+00 GM=-7.869E-22 RPI= 1.020E+1
 309 RO= 8.453E+20 CPI= 5.200E-13 CMU= 1.946E-13 BETAAC=-8.025E-0
 310 FT=-1.753E-10
 311
 312 NAME: Q43 MODEL: RN4
 313
 314 IB=-1.949E-16 IC= 1.950E-16 VBE= 0.000E+00 VBC=-2.228E+0
 315 VCE= 2.228E+00 BETADC=-1.000E+00 GM=-1.274E-21 RPI= 8.923E+1
 316 RO= 1.046E+20 CPI= 3.200E-12 CMU= 1.674E-12 BETAAC=-1.136E-0
 317 FT=-4.159E-11
 318
 319 NAME: Q44 MODEL: RNO
 320
 321 IB=-3.673E-17 IC= 3.673E-17 VBE= 0.000E+00 VBC=-3.359E+0
 322 VCE= 3.359E+00 BETADC=-1.000E+00 GM=-2.400E-22 RPI= 7.138E+1
 323 RO= 8.137E+20 CPI= 4.500E-13 CMU= 3.665E-13 BETAAC=-1.713E-0
 324 FT=-4.677E-11
 325
 326 NAME: Q45 MODEL: RNO
 327
 328 IB=-1.583E-17 IC= 1.584E-17 VBE= 0.000E+00 VBC=-1.448E+0
 329 VCE= 1.448E+00 BETADC=-1.000E+00 GM=-1.074E-22 RPI= 7.138E+1
 330 RO= 8.536E+20 CPI= 4.500E-13 CMU= 4.203E-13 BETAAC=-7.384E-0

331 FT=-1.892E-11
 332
 333 NAME: Q46 MODEL: RNO
 334
 335 IB=-1.583E-17 IC= 1.584E-17 VBE= 0.000E+00 VBC=-1.448E+0
 336 VCE= 1.448E+00 BETADC=-1.000E+00 GM=-1.034E-22 RPI= 7.138E+1
 337 RO= 8.536E+20 CPI= 4.500E-13 CMU= 4.203E-13 BETAAC=-7.384E-0
 338 FT=-1.892E-11
 339
 340 NAME: Q47 MODEL: RPO
 341
 342 IB=-2.110E-06 IC=-1.779E-04 VBF=-1.125E+00 VBC= 1.153E+0
 343 VCE=-1.266E+01 BETADC= 8.434E+01 GM= 6.827E-03 RPI= 1.268E+0
 344 RO= 3.822E+05 CPI= 3.027E-12 CMU= 2.123E-13 BETAAC= 8.659E+0
 345 FT= 3.354E+08
 346
 347 NAME: Q48 MODEL: RPO
 348
 349 IB=-2.110E-06 IC=-1.780E-04 VBE=-1.125E+00 VBC= 1.152E+0
 350 VCE=-1.264E+01 BETADC= 8.433E+01 GM= 6.828E-03 RPI= 1.268E+0
 351 RO= 3.820E+05 CPI= 3.028E-12 CMU= 2.123E-13 BETAAC= 8.657E+0
 352 FT= 3.354E+08
 353
 354 NAME: Q49 MODEL: RNO
 355
 356 IB= 3.695E-07 IC= 4.910E-05 VBE= 1.083E+00 VBC=-1.152E+0
 357 VCE= 1.260E+01 BETADC= 1.329E+02 GM= 1.892E-03 RPI= 7.968E+0
 358 RO= 1.679E+06 CPI= 1.075E-12 CMU= 2.902E-13 BETAAC= 1.508E+0
 359 FT= 2.206E+08
 360
 361 NAME: Q50 MODEL: RN1
 362
 363 IB= 1.421E-06 IC= 1.776E-04 VBE= 1.102E+00 VBC=-1.071E+0
 364 VCE= 2.173E+00 BETADC= 1.249E+02 GM= 6.829E-03 RPI= 2.002E+0
 365 RO= 4.047E+05 CPI= 2.539E-12 CMU= 6.554E-13 BETAAC= 1.367E+0
 366 FT= 3.403E+08
 367
 368 NAME: Q51 MODEL: RN1
 369
 370 IB= 1.421E-06 IC= 1.776E-04 VBE= 1.102E+00 VBC=-1.073E+0
 371 VCE= 2.186E+00 BETADC= 1.250E+02 GM= 6.829E-03 RPI= 2.002E+0
 372 RO= 4.047E+05 CPI= 2.539E-12 CMU= 6.544E-13 BETAAC= 1.367E+0
 373 FT= 3.404E+08
 374
 375 NAME: Q52 MODEL: RN1
 376
 377 IB= 2.456E-07 IC= 2.331E-05 VBF= 1.049E+00 VBC=-8.444E-0
 378 VCE= 1.894E+00 BETADC= 9.490E+01 GM= 8.993E-04 RPI= 1.301E+0
 379 RO= 3.084E+06 CPI= 1.622E-12 CMU= 6.701E-13 BETAAC= 1.170E+0
 380 FT= 6.244E+07
 381
 382 NAME: Q53 MODEL: RN1
 383
 384 IB= 2.456E-07 IC= 2.331E-05 VBF= 1.049E+00 VBC=-8.444E-0
 385 VCE= 1.894E+00 BETADC= 9.490E+01 GM= 8.993E-04 RPI= 1.301E+0

386 $RO = 3.084E+06$ $CPI = 1.622E-12$ $CMU = 6.701E-13$ $BETAAC = 1.170E+0$
 387 $FT = 6.244E+07$
 388
 389 NAME: Q54 MODEL: RP0
 390
 391 $IB = -4.193E-06$ $IC = -3.601E-04$ $VBE = -1.144E+00$ $VBC = 1.204E+0$
 392 $VCE = -1.318E+01$ $BETADC = 8.589E+01$ $GM = 1.373E-02$ $RPI = 6.320E+0$
 393 $RO = 1.897E+05$ $CPI = 5.232E-12$ $CMU = 2.102E-13$ $BETAAC = 8.677E+0$
 394 $FT = 4.016E+08$
 395
 396 NAME: Q55 MODEL: RP1
 397
 398 $IB = -4.414E-06$ $IC = -3.154E-04$ $VBE = -1.127E+00$ $VBC = 1.088E+0$
 399 $VCE = -2.215E+00$ $BETADC = 7.142E+01$ $GM = 1.209E-02$ $RPI = 6.054E+0$
 400 $RO = 1.823E+05$ $CPI = 6.108E-12$ $CMU = 6.160E-13$ $BETAAC = 7.322E+0$
 401 $FT = 2.863E+08$
 402
 403 NAME: Q56 MODEL: RP1
 404
 405 $IB = -1.059E-06$ $IC = -8.490E-05$ $VBE = -1.088E+00$ $VBC = 1.226E+0$
 406 $VCE = -1.334E+01$ $BETADC = 8.020E+01$ $GM = 3.273E-03$ $RPI = 2.612E+0$
 407 $RO = 8.120E+05$ $CPI = 2.600E-12$ $CMU = 2.976E-13$ $BETAAC = 8.547E+0$
 408 $FT = 1.798E+08$
 409
 410 NAME: Q57 MODEL: RN0
 411
 412 $IB = 1.916E-06$ $IC = 3.165E-04$ $VBE = 1.130E+00$ $VBC = -1.789E+0$
 413 $VCE = 1.902E+01$ $BETADC = 1.652E+02$ $GM = 1.209E-02$ $RPI = 1.432E+0$
 414 $RO = 2.795E+05$ $CPI = 2.321E-12$ $CMU = 2.661E-13$ $BETAAC = 1.732E+0$
 415 $FT = 7.439E+08$
 416
 417 NAME: Q58 MODEL: RN0
 418
 419 $IB = 3.526E-07$ $IC = 4.657E-05$ $VBE = 1.082E+00$ $VBC = -1.153E+0$
 420 $VCE = 1.261E+01$ $BETADC = 1.321E+02$ $GM = 1.795E-03$ $RPI = 8.372E+0$
 421 $RO = 1.770E+06$ $CPI = 1.062E-12$ $CMU = 2.902E-13$ $BETAAC = 1.503E+0$
 422 $FT = 2.113E+08$
 423
 424 NAME: Q59 MODEL: RN1
 425
 426 $IB = 4.235E-07$ $IC = 4.493E-05$ $VBE = 1.066E+00$ $VBC = -8.333E+0$
 427 $VCE = 1.900E+00$ $BETADC = 1.061E+02$ $GM = 1.732E-03$ $RPI = 7.214E+0$
 428 $RO = 1.598E+06$ $CPI = 1.758E-12$ $CMU = 6.720E-13$ $BETAAC = 1.250E+0$
 429 $FT = 1.135E+08$
 430
 431 NAME: Q60 MODEL: RN1
 432
 433 $IB = 2.438E-06$ $IC = 3.179E-04$ $VBE = 1.118E+00$ $VBC = -1.072E+0$
 434 $VCE = 2.190E+00$ $BETADC = 1.304E+02$ $GM = 1.219E-02$ $RPI = 1.142E+0$
 435 $RO = 2.257E+05$ $CPI = 3.354E-12$ $CMU = 6.604E-13$ $BETAAC = 1.392E+0$
 436 $FT = 4.832E+08$
 437
 438 NAME: Q61 MODEL: RP0
 439
 440 $IB = -3.369E-06$ $IC = -2.895E-04$ $VBE = -1.138E+00$ $VBC = 1.223E+0$

441 VCE=-1.337E+01 RFTADC= 8.595E+01 GM= 1.107E-02 RPT= 7.888E+0
442 R0= 2.368E+05 CPI= 4.357E-12 CMU= 2.088E-13 BETAAC= 8.729E+0
443 FT= 3.857E+08
444
445 NAME: Q62 MODEL: RN1LC
446
447 IB= 2.202E-06 IC= 2.811E-04 VBE= 1.115E+00 VBC= 0.000E+0
448 VCE= 1.115E+00 BETADC= 1.277E+02 GM= 1.079E-02 RPI= 1.269E+0
449 R0= 2.517E+05 CPI= 3.164E-12 CMU= 8.193E-13 BETAAC= 1.369E+0
450 FT= 4.310E+08
451
452 NAME: Q63 MODEL: RP1LC
453
454 IB=-3.990E-06 IC=-2.794E-04 VBE=-1.124E+00 VBC= 0.000E+0
455 VCE=-1.124E+00 BETADC= 7.002E+01 GM= 1.072E-02 RPI= 6.713E+0
456 R0= 2.024E+05 CPI= 5.659E-12 CMU= 9.119E-13 BETAAC= 7.195E+0
457 FT= 2.596E+08
458
459 NAME: Q64 MODEL: RN1
460
461 IA= 5.039E-07 IC= 6.390E-05 VBE= 1.072E+00 VBC=-1.237E+0
462 VCE= 1.344E+01 RFTADC= 1.268E+02 GM= 2.464E-03 RPI= 5.949E+0
463 R0= 1.304E+06 CPI= 1.820E-12 CMU= 4.238E-13 BETAAC= 1.476E+0
464 FT= 1.748E+08
465
466 NAME: Q65 MODEL: RN1
467
468 IB= 1.994E-06 IC= 2.936E-04 VBE= 1.112E+00 VBC=-1.149E+0
469 VCE= 1.260E+01 BETADC= 1.472E+02 GM= 1.127E-02 RPI= 1.407E+0
470 R0= 2.800E+05 CPI= 2.997E-12 CMU= 4.309E-13 BETAAC= 1.586E+0
471 FT= 5.234E+08
472
473 NAME: Q66 MODEL: RN1LC
474
475 IB= 2.291E-06 IC= 2.933E-04 VBE= 1.116E+00 VBC= 0.000E+0
476 VCE= 1.116E+00 BETADC= 1.280E+02 GM= 1.125E-02 RPT= 1.218E+0
477 R0= 2.412E+05 CPI= 3.236E-12 CMU= 8.202E-13 BETAAC= 1.371E+0
478 FT= 4.414E+08
479
480 NAME: Q67 MODEL: RNAC
481
482 IB= 6.197E-06 IC= 8.519E-04 VBE= 1.085E+00 VBC=-1.345E+0
483 VCE= 1.493E+01 BETADC= 1.375E+02 GM= 3.283E-02 RPI= 4.738E+0
484 R0= 9.946E+04 CPI= 1.557E-11 CMU= 1.969E-12 BETAAC= 1.555E+0
485 FT= 2.980E+08
486
487 NAME: Q68 MODEL: RPBC
488
489 IB=-1.022E+05 IC=-8.479E-04 VBE=-1.093E+00 VBC= 1.384E+0
490 VCE=-1.493E+01 BETADC= 8.300E+01 GM= 3.268E-02 RPT= 2.691E+0
491 R0= 8.315E+04 CPI= 2.209E-11 CMU= 1.332E-12 BETAAC= 8.793E+0
492 FT= 2.220E+08
493
494 NAME: Q69 MODEL: RN1LC
495

496 $IB = 1.440E-06$ $IC = 1.776E-04$ $VBE = 1.103E+00$ $VBC = 0.000E+0$
 497 $VCE = 1.103E+00$ $BETADC = 1.233E+02$ $GM = 6.828E-03$ $RPI = 1.974E+0$
 498 $RO = 3.988E+05$ $CPI = 2.554E-12$ $CMII = 8.119E-13$ $BETAAC = 1.348E+0$
 499 $FT = 3.229E+08$

500
 501 NAME: Q70 MODEL: RN1LC
 502
 503 $IB = 1.440E-06$ $IC = 1.776E-04$ $VBE = 1.103E+00$ $VBC = 0.000E+0$
 504 $VCE = 1.103E+00$ $BETADC = 1.233E+02$ $GM = 6.828E-03$ $RPI = 1.974E+0$
 505 $RO = 3.988E+05$ $CPI = 2.554E-12$ $CMII = 8.119E-13$ $BETAAC = 1.348E+0$
 506 $FT = 3.229E+08$

507
 508 NAME: Q71 MODEL: RN1LC
 509
 510 $IB = 5.520E-07$ $IC = 6.050E-05$ $VBE = 1.075E+00$ $VBC = 0.000E+0$
 511 $VCE = 1.075E+00$ $BETADC = 1.096E+02$ $GM = 2.332E-03$ $RPI = 5.433E+0$
 512 $RO = 1.173E+06$ $CPI = 1.857E-12$ $CMII = 8.039E-13$ $BETAAC = 1.267E+0$
 513 $FT = 1.395E+08$

514
 515 NAME: Q72 MODEL: RP1LC
 516
 517 $IB = -1.102E-06$ $IC = -7.298E-05$ $VBE = -1.089E+00$ $VBC = 0.000E+0$
 518 $VCE = -1.049E+00$ $BETADC = 6.615E+01$ $GM = 2.808E-03$ $RPI = 2.506E+0$
 519 $RO = 7.782E+05$ $CPI = 2.644E-12$ $CMII = 8.724E-13$ $BETAAC = 7.038E+0$
 520 $FT = 1.271E+08$

521
 522 NAME: Q73 MODEL: RNO
 523
 524 $IB = -1.138E-16$ $IC = 1.138E-16$ $VBE = 0.000E+00$ $VBC = -1.041E+0$
 525 $VCE = -1.041E+01$ $BETADC = -1.000E+00$ $GM = -7.434E-22$ $RPI = 7.138E+1$
 526 $RO = 6.940E+20$ $CPI = 4.500E-13$ $CMII = 2.960E-13$ $BETAAC = -5.307E-0$
 527 $FT = -1.586E-10$

528
 529 NAME: Q74 MODEL: RN1
 530
 531 $IB = -3.290E-16$ $IC = 3.270E-16$ $VBE = -7.107E-04$ $VBC = -1.495E+0$
 532 $VCE = 1.495E+01$ $BETADC = -9.941E-01$ $GM = -2.136E-21$ $RPI = 3.569E+1$
 533 $RO = 3.169E+20$ $CPI = 8.198E-13$ $CMII = 4.078E-13$ $BETAAC = -7.625E-0$
 534 $FT = -2.770E-10$

535
 536 NAME: Q75 MODEL: RP1
 537
 538 $IB = 2.275E-16$ $IC = -2.289E-16$ $VBE = -7.107E-04$ $VBC = 1.495E+0$
 539 $VCE = -1.495E+01$ $BETADC = -1.000E+00$ $GM = -1.519E-21$ $RPI = -5.029E+1$
 540 $RO = 4.226E+20$ $CPI = 9.502E-13$ $CMII = 2.790E-13$ $BETAAC = -7.639E-0$
 541 $FT = -1.967E-10$

542
 543 NAME: Q76 MODEL: RP0
 544
 545 $IB = -1.232E-17$ $IC = -1.233E-17$ $VBE = 0.000E+00$ $VBC = 1.610E+0$
 546 $VCE = -1.610E+00$ $BETADC = -1.000E+00$ $GM = -8.475E-23$ $RPI = 1.020E+0$
 547 $RO = 1.202E+21$ $CPI = 5.200E-13$ $CMII = 3.749E-13$ $BETAAC = -8.643E-0$
 548 $FT = -1.507E-11$

549
 550 NAME: Q77 MODEL: RP1

551
 552 IB= 2.465E-17 IC=-2.465E-17 VBE= 0.000E+00 VBC= 1.610E+0
 553 VCE=-1.610E+00 BETADC=-1.000E+00 GM=-1.695E-22 RPI= 5.099E+1
 554 RO= 6.010E+20 CPI= 9.500E-13 CMU= 5.374E-13 BETAAC=-8.643E-0
 555 FT=-1.814E-11
 556
 557 NAME: Q78 MODEL: RP0
 558
 559 IB= 1.232E-17 IC=-1.233E-17 VBF= 0.000E+00 VBC= 1.610E+0
 560 VCE=-1.610E+00 BETADC=-1.000E+00 GM=-8.475E-23 RPI= 1.020E+1
 561 RO= 1.202E+21 CPI= 5.200E-13 CMU= 3.749E-13 BETAAC=-8.643E-0
 562 FT=-1.507E-11
 563
 564 NAME: Q79 MODEL: RN1
 565
 566 IB=-3.291E-17 IC= 3.291E-17 VBE= 0.000E+00 VBC=-1.505E+0
 567 VCE= 1.505E+00 BETADC=-1.000E+00 GM=-2.150E-22 RPI= 3.569E+1
 568 RO= 4.262E+20 CPI= 8.200E-13 CMU= 6.191E-13 BETAAC=-7.674E-0
 569 FT=-2.378E-11
 570
 571 NAME: Q80 MODEL: RN1
 572
 573 IB=-3.291E-17 IC= 3.291E-17 VBE= 0.000E+00 VBC=-1.505E+0
 574 VCE= 1.505E+00 BETADC=-1.000E+00 GM=-2.150E-22 RPI= 3.569E+1
 575 RO= 4.262E+20 CPI= 8.200E-13 CMU= 6.191E-13 BETAAC=-7.674E-0
 576 FT=-2.378E-11
 577
 578 NAME: Q81 MODEL: RN1
 579
 580 IB=-3.291E-17 IC= 3.291E-17 VBE= 0.000E+00 VBC=-1.505E+0
 581 VCE= 1.505E+00 BETADC=-1.000E+00 GM=-2.150E-22 RPI= 3.569E+1
 582 RO= 4.262E+20 CPI= 8.200E-13 CMU= 6.191E-13 BETAAC=-7.674E-0
 583 FT=-2.378E-11
 584
 585 NAME: Q82 MODEL: RN1
 586
 587 IB=-3.291E-17 IC= 3.291E-17 VBE= 0.000E+00 VBC=-1.505E+0
 588 VCE= 1.505E+00 BETADC=-1.000E+00 GM=-2.150E-22 RPI= 3.569E+1
 589 RO= 4.262E+20 CPI= 8.200E-13 CMU= 6.191E-13 BETAAC=-7.674E-0
 590 FT=-2.378E-11
 591
 592 NAME: Q83 MODEL: RP0
 593
 594 IB= 1.244E-16 IC=-1.244E-16 VBE= 0.000E+00 VBC= 1.626E+0
 595 VCE=-1.626E+01 BETADC=-1.000E+00 GM=-8.557E-22 RPI= 1.020E+1
 596 RO= 8.214E+20 CPI= 5.200E-13 CMU= 1.895E-13 BETAAC=-8.726E-0
 597 FT=-1.920E-10
 598
 599 NAME: Q84 MODEL: RN8C
 600
 601 IB=-3.917E-16 IC= 3.918E-16 VBF= 0.000E+00 VBC=-2.239E+0
 602 VCE= 2.239E+00 BETADC=-1.000E+00 GM=-2.559E-21 RPI= 4.462E+1
 603 RO= 5.229E+19 CPI= 6.200E-12 CMU= 2.764E-12 BETAAC=-1.142E-0
 604 FT=-4.544E-11
 605

606 NAME: QAS MODEL: RNO

607

608 IB=-3.740E-17 IC= 3.740E-17 VBF= 0.000E+00 VBC=-3.420E+0

609 VCE= 3.420E+00 BETADC=-1.000E+00 GM=-2.443E-22 RPI= 7.138E+1

610 RO= 8.125E+20 CPI= 4.500E-13 CMU= 3.653E-13 BETAAC=-1.744E-0

611 FT=-4.769E-11

1 POST-RADIATION DINS PHOTOPREAMPLIFIER OPERATING POINTS

2 (TEMPERATURE 25 DEGREES C)

3 ----- VOLTAGE SUPPLY CURRENTS -----

NAME	CURRNT	NAME	CURRNT
VPOS	-3.161E-03	VNEG	3.567E-03
TOTAL POWER = 101 MW (ONE CHANNEL)			

9

10 ----- ZENFR DIODE -----

11

12 NAME: DZ1 MODEL: DZR

13

14 ID=-2.569E-04 VD=-6.202E+00 REG= 1.000E+02 CAP= 1.605E-1

15

16 ----- RJT'S -----

17

18 NAME: Q1 MODEL: RPO

19

IR=-6.097E-06	IC=-6.015E-05	VBE=-6.625E-01	VRC= 1.213E+0
VCE=-1.279E+01	BETADC= 9.865E+00	GM= 2.334E-03	RPI= 5.030E+0
RO= 1.164E+06	CPI= 1.474E-12	CMII= 1.891E-13	BETAAC= 1.174E+0
FT= 2.239E+08			

20

21

IR=-6.079E-06	IC=-6.002E-05	VBE=-6.625E-01	VRC= 1.223E+0
VCE=-1.289E+01	BETADC= 9.874E+00	GM= 2.329E-03	RPI= 5.045E+0
RO= 1.168E+06	CPI= 1.472E-12	CMII= 1.846E-13	BETAAC= 1.175E+0
FT= 2.238E+08			

22

23

24

25

26 NAME: Q2 MODEL: RPO

27

IR=-6.079E-06	IC=-6.002E-05	VBE=-6.625E-01	VRC= 1.223E+0
VCE=-1.289E+01	BETADC= 9.874E+00	GM= 2.329E-03	RPI= 5.045E+0
RO= 1.168E+06	CPI= 1.472E-12	CMII= 1.846E-13	BETAAC= 1.175E+0
FT= 2.238E+08			

28

29

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32

33 NAME: Q3 MODEL: RNO

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40 NAME: Q4 MODEL: RN1

41

42

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46

47 NAME: Q5 MODEL: RN1

48

49

50

51

52

53

54 NAME: Q6 MODEL: RN1

55

56 $IB = 1.902E-06$ $IC = 2.331E-05$ $VBE = 6.147E-01$ $VBC = -2.876E-01$
 57 $VCE = 9.022E-01$ $BETADC = 1.226E+01$ $GM = 9.053E-04$ $RPI = 1.724E+01$
 58 $RO = 3.129E+06$ $CPI = 1.372E-12$ $CMU = 7.372E-13$ $BETAAC = 1.561E+01$
 59 $FT = 6.832E+07$
 60
 61 NAME: Q7 MODEL: RN1
 62
 63 $IB = 1.902E-06$ $IC = 2.331E-05$ $VBE = 6.147E-01$ $VBC = -2.876E-01$
 64 $VCE = 9.022E-01$ $BETADC = 1.226E+01$ $GM = 9.053E-04$ $RPI = 1.724E+01$
 65 $RO = 3.129E+06$ $CPI = 1.372E-12$ $CMU = 7.372E-13$ $BETAAC = 1.561E+01$
 66 $FT = 6.832E+07$
 67
 68 NAME: Q8 MODEL: RP0
 69
 70 $IB = -1.146E-05$ $IC = -1.323E-04$ $VBE = -6.839E-01$ $VBC = 1.398E+01$
 71 $VCE = -1.467E+01$ $BETADC = 1.135E+01$ $GM = 5.125E-03$ $RPI = 2.586E+01$
 72 $RO = 5.415E+05$ $CPI = 2.295E-12$ $CMU = 1.774E-13$ $BETAAC = 1.325E+01$
 73 $FT = 3.299E+08$
 74
 75 NAME: Q9 MODEL: RP1
 76
 77 $IB = -2.788E-05$ $IC = -2.647E-04$ $VBE = -6.928E-01$ $VBC = 6.595E-01$
 78 $VCE = -1.352E+00$ $BETADC = 9.495E+00$ $GM = 1.024E-02$ $RPI = 1.076E+01$
 79 $RO = 2.198E+05$ $CPI = 5.164E-12$ $CMU = 7.185E-13$ $BETAAC = 1.102E+01$
 80 $FT = 2.771E+08$
 81
 82 NAME: Q10 MODEL: RP1
 83
 84 $IB = -1.074E-05$ $IC = -1.050E-04$ $VBE = -6.595E-01$ $VBC = 1.325E+01$
 85 $VCE = -1.391E+01$ $BETADC = 9.777E+00$ $GM = 4.077E-03$ $RPI = 2.864E+01$
 86 $RO = 6.771E+05$ $CPI = 2.614E-12$ $CMU = 2.580E-13$ $BETAAC = 1.168E+01$
 87 $FT = 2.259E+08$
 88
 89 NAME: Q11 MODEL: RNO
 90
 91 $IB = 1.052E-05$ $IC = 2.755E-04$ $VBE = 6.938E-01$ $VBC = -1.995E+00$
 92 $VCE = 2.065E+01$ $BETADC = 2.618E+01$ $GM = 1.063E-02$ $RPI = 2.871E+01$
 93 $RO = 3.311E+05$ $CPI = 1.964E-12$ $CMU = 2.476E-13$ $BETAAC = 3.051E+00$
 94 $FT = 7.650E+08$
 95
 96 NAME: Q12 MODEL: RNO
 97
 98 $IB = 2.857E-06$ $IC = 5.399E-05$ $VBE = 6.506E-01$ $VBC = -1.287E+01$
 99 $VCE = 1.352E+01$ $BETADC = 1.890E+01$ $GM = 2.095E-03$ $RPI = 1.106E+01$
 100 $RO = 1.578E+06$ $CPI = 9.585E-13$ $CMU = 2.684E-13$ $BETAAC = 2.316E+01$
 101 $FT = 2.718E+08$
 102
 103 NAME: Q13 MODEL: RN1
 104
 105 $IB = 3.208E-06$ $IC = 4.513E-05$ $VBE = 6.321E-01$ $VBC = -3.844E+01$
 106 $VCE = 1.016E+00$ $BETADC = 1.407E+01$ $GM = 1.752E-03$ $RPI = 1.004E+01$
 107 $RO = 1.615E+06$ $CPI = 1.510E-12$ $CMU = 7.292E-13$ $BETAAC = 1.750E+01$
 108 $FT = 1.246E+08$
 109
 110 NAME: Q14 MODEL: RN1

```

111
112   IR= 1.449E-05   IC= 2.815E-04   VBE= 6.870E-01   VBC=-6.433E-0
113   VCE= 1.326E+00   BETADC= 1.943E+01   GM= 1.089E-02   RPI= 2.112E+0
114   RO= 2.569E+05   CPI= 2.900E-12   CMII= 8.564E-13   BETAAC= 2.299E+0
115   FT= 4.613E+08

116
117   NAME: Q15      MODEL: RPO
118
119   IB=-1.932E-05   IC=-2.344E-04   VBE=-7.014E-01   VBC= 1.324E+0
120   VCE=-1.394E+01   BETADC= 1.213E+01   GM= 9.054E-03   RPI= 1.540E+0
121   RO= 3.014E+05   CPI= 3.517E-12   CMII= 1.816E-13   BETAAC= 1.395E+0
122   FT= 3.896E+08

123
124   NAME: Q16      MODEL: RN1LC
125
126   IR= 1.088E-05   IC= 1.997E-04   VBE= 6.731E-01   VBC= 0.000E+0
127   VCE= 6.731E-01   BETADC= 1.835E+01   GM= 7.733E-03   RPI= 2.840E+0
128   RO= 3.601E+05   CPI= 2.428E-12   CMII= 9.957E-13   BETAAC= 2.196E+0
129   FT= 3.505E+08

130
131   NAME: Q17      MODEL: RP1LC
132
133   IB=-2.106E-05   IC=-1.895E-04   VBE=-6.826E-01   VBC= 0.000E+0
134   VCE= 6.826E-01   BETADC= 9.001E+00   GM= 7.341E-03   RPI= 1.436E+0
135   RO= 3.051E+05   CPI= 4.110E-12   CMII= 1.013E-12   BETAAC= 1.054E+0
136   FT= 2.281E+08

137
138   NAME: Q18      MODEL: RN1
139
140   IB= 4.500E-06   IC= 8.084E-05   VBE= 6.433E-01   VBC=-1.326E+0
141   VCE= 1.390E+01   BETADC= 1.796E+01   GM= 3.138E-03   RPI= 7.077E+0
142   RO= 1.059E+06   CPI= 1.653E-12   CMII= 3.952E-13   BETAAC= 2.221E+0
143   FT= 2.438E+08

144
145   NAME: Q19      MODEL: RN1
146
147   IB= 1.171E-05   IC= 2.557E-04   VBE= 6.756E-01   VBC=-1.283E+0
148   VCE= 1.351E+01   BETADC= 2.184E+01   GM= 9.902E-03   RPI= 2.631E+0
149   RO= 3.308E+05   CPI= 2.535E-12   CMII= 4.010E-13   BETAAC= 2.605E+0
150   FT= 5.348E+08

151
152   NAME: Q20      MODEL: RN1LC
153
154   IB= 1.336E-05   IC= 2.541E-04   VBE= 6.801E-01   VBC= 0.000E+0
155   VCE= 6.801E-01   BETADC= 1.903E+01   GM= 9.831E-03   RPI= 2.301E+0
156   RO= 2.625E+05   CPI= 2.746E-12   CMII= 1.089E-12   BETAAC= 2.263E+0
157   FT= 4.080E+08

158
159   NAME: Q21      MODEL: RN4
160
161   IB= 2.384E-05   IC= 4.619E-04   VBE= 6.546E-01   VBC=-1.430E+0
162   VCE= 1.496E+01   BETADC= 1.938E+01   GM= 1.792E-02   RPI= 1.323E+0
163   RO= 1.874E+05   CPI= 7.161E-12   CMII= 1.120E-12   BETAAC= 2.371E+0
164   FT= 3.444E+08
165

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166 NAME: Q22 MODEL: RP4
 167
 168 $IB = -4.513E-05$ $IC = -4.520E-04$ $VBE = -6.617E-01$ $VBC = 1.430E+0$
 169 $VCE = -1.496E+01$ $BETADC = 1.001E+01$ $GM = 1.754E-02$ $RPI = 6.808E+0$
 170 $RO = 1.596E+05$ $CPI = 1.061E-11$ $CMII = 7.320E-13$ $BETAAC = 1.194E+0$
 171 $FT = 2.462E+08$
 172
 173 NAME: Q23 MODEL: RN1LC
 174
 175 $IB = 3.897E-06$ $IC = 5.726E-05$ $VBE = 6.385E-01$ $VBC = 0.000E+0$
 176 $VCE = 6.385E-01$ $BETADC = 1.469E+01$ $GM = 2.223E-03$ $RPI = 8.213E+0$
 177 $RO = 1.266E+06$ $CPI = 1.586E-12$ $CMII = 8.371E-13$ $BETAAC = 1.826E+0$
 178 $FT = 1.460E+08$
 179
 180 NAME: Q24 MODEL: RN1LC
 181
 182 $IB = 3.896E-06$ $IC = 5.724E-05$ $VBE = 6.385E-01$ $VBC = 0.000E+0$
 183 $VCE = 6.385E-01$ $BETADC = 1.469E+01$ $GM = 2.222E-03$ $RPI = 8.215E+0$
 184 $RO = 1.267E+06$ $CPI = 1.586E-12$ $CMII = 8.371E-13$ $BETAAC = 1.825E+0$
 185 $FT = 1.460E+08$
 186
 187 NAME: Q25 MODEL: RN1LC
 188
 189 $IB = 3.698E-06$ $IC = 5.364E-05$ $VBE = 6.368E-01$ $VBC = 0.000E+0$
 190 $VCE = 6.368E-01$ $BETADC = 1.451E+01$ $GM = 2.082E-03$ $RPI = 8.672E+0$
 191 $RO = 1.352E+06$ $CPI = 1.564E-12$ $CMII = 8.345E-13$ $BETAAC = 1.806E+0$
 192 $FT = 1.382E+08$
 193
 194 NAME: Q26 MODEL: RP1LC
 195
 196 $IB = -6.876E-06$ $IC = -5.010E-05$ $VBE = -6.448E-01$ $VBC = 0.000E+0$
 197 $VCE = -6.448E-01$ $BETADC = 7.296E+00$ $GM = 1.945E-03$ $RPI = 4.528E+0$
 198 $RO = 1.158E+06$ $CPI = 2.099E-12$ $CMII = 8.912E-13$ $BETAAC = 8.805E+0$
 199 $FT = 1.035E+08$
 200
 201 NAME: Q27 MODEL: RN1LC
 202
 203 $IB = 1.290E-05$ $IC = 2.440E-04$ $VBE = 6.789E-01$ $VBC = 0.000E+0$
 204 $VCE = 6.789E-01$ $BETADC = 1.892E+01$ $GM = 9.441E-03$ $RPI = 2.385E+0$
 205 $RO = 2.829E+05$ $CPI = 2.687E-12$ $CMII = 1.065E-12$ $BETAAC = 2.252E+0$
 206 $FT = 4.005E+08$
 207
 208 NAME: Q28 MODEL: RN1LC
 209
 210 $IB = 1.290E-05$ $IC = 2.440E-04$ $VBE = 6.789E-01$ $VBC = 0.000E+0$
 211 $VCE = 6.789E-01$ $BETADC = 1.892E+01$ $GM = 9.441E-03$ $RPI = 2.385E+0$
 212 $RO = 2.829E+05$ $CPI = 2.687E-12$ $CMII = 1.065E-12$ $BETAAC = 2.252E+0$
 213 $FT = 4.005E+08$
 214
 215 NAME: Q29 MODEL: RN1LC
 216
 217 $IB = 1.290E-05$ $IC = 2.440E-04$ $VBE = 6.789E-01$ $VBC = 0.000E+0$
 218 $VCE = 6.789E-01$ $BETADC = 1.892E+01$ $GM = 9.441E-03$ $RPI = 2.385E+0$
 219 $RO = 2.829E+05$ $CPI = 2.687E-12$ $CMII = 1.065E-12$ $BETAAC = 2.252E+0$
 220 $FT = 4.005E+08$

221
 222 NAME: Q30 MODEL: RNO
 223
 224 IB=-7.394E-11 IC= 7.422E-11 VBE= 0.000E+00 VBC=-1.218E+0
 225 VCE= 1.218E+01 BETADC=-1.004E+00 GM=-1.502E-14 RPI= 8.237E+1
 226 RO= 3.878E+13 CPI= 4.500E-13 CMU= 2.704E-13 BETAAC=-1.237E-0
 227 FT=-3.318E-03
 228
 229 NAME: Q31 MODEL: RNO
 230
 231 IB= 2.800E-06 IC= 5.401E-05 VBE= 6.499E-01 VBC=-1.504E+0
 232 VCE= 1.569E+01 BETADC= 1.929E+01 GM= 2.096E-03 RPI= 1.129E+0
 233 RO= 1.618E+06 CPI= 9.518E-13 CMU= 2.599E-13 BETAAC= 2.366E+0
 234 FT= 2.753E+08
 235
 236 NAME: Q32 MODEL: RNO
 237
 238 IB= 2.801E-06 IC= 5.402E-05 VBE= 6.499E-01 VBC=-1.504E+0
 239 VCE= 1.569E+01 BETADC= 1.929E+01 GM= 2.097E-03 RPI= 1.129E+0
 240 RO= 1.617E+06 CPI= 9.519E-13 CMU= 2.599E-13 BETAAC= 2.366E+0
 241 FT= 2.754E+08
 242
 243 NAME: Q33 MODEL: RNO
 244
 245 IB= 3.229E-06 IC= 6.290E-05 VBE= 6.546E-01 VBC=-1.317E+0
 246 VCE= 1.382E+01 BETADC= 1.948E+01 GM= 2.440E-03 RPI= 9.740E+0
 247 RO= 1.358E+06 CPI= 1.003E-12 CMU= 2.673E-13 BETAAC= 2.377E+0
 248 FT= 3.059E+08
 249
 250 NAME: Q34 MODEL: RNO
 251
 252 IB= 3.229E-06 IC= 6.290E-05 VBE= 6.546E-01 VBC=-1.317E+0
 253 VCE= 1.382E+01 BETADC= 1.948E+01 GM= 2.440E-03 RPI= 9.740E+0
 254 RO= 1.358E+06 CPI= 1.003E-12 CMU= 2.673E-13 BETAAC= 2.377E+0
 255 FT= 3.059E+08
 256
 257 NAME: Q35 MODEL: RP0
 258
 259 IB= 4.435E-12 IC=-4.449E-12 VBE= 0.000E+00 VBC= 1.044E+0
 260 VCE=-1.044E+00 BETADC=-1.003E+00 GM=-9.481E-16 RPI= 1.210E+1
 261 RO= 7.094E+13 CPI= 5.200E-13 CMU= 3.803E-13 BETAAC=-1.147E-0
 262 FT=-1.676E-04
 263
 264 NAME: Q36 MODEL: RP1
 265
 266 IB= 8.869E-12 IC=-8.898E-12 VBE= 0.000E+00 VBC= 1.044E+0
 267 VCE=-1.044E+00 BETADC=-1.003E+00 GM=-1.806E-15 RPI= 6.048E+1
 268 RO= 3.547E+13 CPI= 9.500E-13 CMU= 5.451E-13 BETAAC=-1.147E-0
 269 FT=-2.019E-04
 270
 271 NAME: Q37 MODEL: RP0
 272
 273 IB= 4.435E-12 IC=-4.449E-12 VBF= 0.000E+00 VBC= 1.044E+0
 274 VCE=-1.044E+00 BETADC=-1.003E+00 GM=-9.481E-16 RPI= 1.210E+1
 275 RO= 7.094E+13 CPI= 5.200E-13 CMU= 3.803E-13 BETAAC=-1.147E-0

276 FT=-1.676E-04
 277
 278 NAME: Q38 MODEL: RN1
 279
 280 IB=-1.260E-11 IC= 1.264E-11 VBE= 0.000E+00 VBC=-1.038E+
 281 VCE= 1.038E+00 BETADC=-1.003E+00 GM=-2.559E-15 RPI= 4.119E+
 282 RO= 2.500E+13 CPI= 8.200E-13 CMU= 6.263E-13 BETAAC=-1.054E-
 283 FT=-2.816E-04
 284
 285 NAME: Q39 MODEL: RN1
 286
 287 IB=-1.260E-11 IC= 1.264E-11 VBE= 0.000E+00 VBC=-1.038E+
 288 VCE= 1.038E+00 BETADC=-1.003E+00 GM=-2.559E-15 RPI= 4.119E+
 289 RO= 2.500E+13 CPI= 8.200E-13 CMU= 6.263E-13 BETAAC=-1.054E-
 290 FT=-2.816E-04
 291
 292 NAME: Q40 MODEL: RN1
 293
 294 IB=-1.260E-11 IC= 1.264E-11 VBE= 0.000E+00 VBC=-1.038E+
 295 VCE= 1.038E+00 BETADC=-1.003E+00 GM=-2.559E-15 RPI= 4.119E+
 296 RO= 2.500E+13 CPI= 8.200E-13 CMU= 6.263E-13 BETAAC=-1.054E-
 297 FT=-2.816E-04
 298
 299 NAME: Q41 MODEL: RN1
 300
 301 IB=-1.260E-11 IC= 1.264E-11 VBE= 0.000E+00 VBC=-1.038E+
 302 VCE= 1.038E+00 BETADC=-1.003E+00 GM=-2.559E-15 RPI= 4.119E+
 303 RO= 2.500E+13 CPI= 8.200E-13 CMU= 6.263E-13 BETAAC=-1.054E-
 304 FT=-2.816E-04
 305
 306 NAME: Q42 MODEL: RP0
 307
 308 IB= 6.316E-11 IC=-6.341E-11 VBE= 0.000E+00 VBC= 1.487E+
 309 VCE=-1.497E+01 BETADC=-1.004E+00 GM=-1.350E-14 RPI= 1.210E+
 310 RO= 4.908E+13 CPI= 5.200E-13 CMU= 1.728E-13 BETAAC=-1.033E-
 311 FT=-3.102E-03
 312
 313 NAME: Q43 MODEL: RN4
 314
 315 IB=-6.582E-11 IC= 6.603E-11 VBE= 0.000E+00 VBC=-1.356E+
 316 VCE= 1.356E+00 BETADC=-1.003E+00 GM=-1.337E-14 RPI= 1.030E+
 317 RO= 6.190E+12 CPI= 3.200E-12 CMU= 1.730E-12 BETAAC=-1.376E-
 318 FT=-4.316E-04
 319
 320 NAME: Q44 MODEL: RN0
 321
 322 IB=-1.258E-11 IC= 1.262E-11 VBE= 0.000E+00 VBC=-2.073E+
 323 VCE= 2.073E+00 BETADC=-1.003E+00 GM=-2.555E-15 RPI= 8.237E+
 324 RO= 4.869E+13 CPI= 4.500E-13 CMU= 3.788E-13 BETAAC=-2.105E-
 325 FT=-4.907E-04
 326
 327 NAME: Q45 MODEL: RN0
 328
 329 IB=-6.301E-12 IC= 6.321E-12 VBE= 0.000E+00 VBC=-1.038E+
 330 VCE= 1.038E+00 BETADC=-1.003E+00 GM=-1.280E-15 RPI= 8.237E+

331 RO= 5.000E+13 CPI= 4.500E-13 CMII= 4.227E-13 BETAAC=-1.054E-0
 332 FT=-2.334E-04
 333
 334 NAME: Q46 MODEL: RNO
 335
 336 IB=-6.301E-12 IC= 6.321E-12 VBE= 0.000E+00 VBC=-1.038E+0
 337 VCE= 1.038E+00 BETADC=-1.003E+00 GM=-1.280E-15 RPI= 8.237E+1
 338 RO= 5.000E+13 CPI= 4.500E-13 CMII= 4.227E-13 BETAAC=-1.054E-0
 339 FT=-2.334E-04
 340
 341 NAME: Q47 MODEL: RPO
 342
 343 IB=-1.420E-05 IC=-1.635E-04 VBE=-6.906E-01 VBC= 1.280E+0
 344 VCE=-1.349E+01 BETADC= 1.152E+01 GM= 6.328E-03 RPI= 2.113E+0
 345 RO= 4.304E+05 CPI= 2.691E-12 CMII= 1.830E-13 BETAAC= 1.337E+0
 346 FT= 3.505E+08
 347
 348 NAME: Q48 MODEL: RPO
 349
 350 IB=-1.421E-05 IC=-1.637E-04 VBE=-6.906E-01 VBC= 1.282E+0
 351 VCE=-1.351E+01 BETADC= 1.152E+01 GM= 6.335E-03 RPI= 2.111E+0
 352 RO= 4.301E+05 CPI= 2.692E-12 CMII= 1.828E-13 BETAAC= 1.337E+0
 353 FT= 3.507E+08
 354
 355 NAME: Q49 MODEL: RNO
 356
 357 IB= 3.183E-06 IC= 6.156E-05 VBE= 6.541E-01 VBC=-1.282E+0
 358 VCE= 1.347E+01 BETADC= 1.934E+01 GM= 2.388E-03 RPI= 9.887E+0
 359 RO= 1.383E+06 CPI= 9.970E-13 CMII= 2.688E-13 BETAAC= 2.361E+0
 360 FT= 3.003E+08
 361
 362 NAME: Q50 MODEL: RN1
 363
 364 IB= 9.015E-06 IC= 1.606E-04 VBE= 6.666E-01 VBC=-6.755E-0
 365 VCE= 1.342E+00 BETADC= 1.781E+01 GM= 6.222E-03 RPI= 3.449E+0
 366 RO= 4.531E+05 CPI= 2.192E-12 CMII= 7.348E-13 BETAAC= 2.146E+0
 367 FT= 3.384E+08
 368
 369 NAME: Q51 MODEL: RN1
 370
 371 IB= 9.016E-06 IC= 1.605E-04 VBE= 6.666E-01 VBC=-6.541E-0
 372 VCE= 1.321E+00 BETADC= 1.781E+01 GM= 6.221E-03 RPI= 3.449E+0
 373 RO= 4.530E+05 CPI= 2.192E-12 CMII= 7.396E-13 BETAAC= 2.146E+0
 374 FT= 3.377E+08
 375
 376 NAME: Q52 MODEL: RN1
 377
 378 IB= 1.902E-06 IC= 2.334E-05 VBE= 6.147E-01 VBC=-3.698E-0
 379 VCE= 9.845E-01 BETADC= 1.227E+01 GM= 9.067E-04 RPI= 1.724E+0
 380 RO= 3.128E+06 CPI= 1.372E-12 CMII= 7.201E-13 BETAAC= 1.563E+0
 381 FT= 6.899E+07
 382
 383 NAME: Q53 MODEL: RN1
 384
 385 IB= 1.902E-06 IC= 2.334E-05 VBE= 6.147E-01 VBC=-3.698E-0

386 VCE= 9.845E-01 BETADC= 1.227E+01 GM= 9.067E-04 RPI= 1.724E+0
 387 RD= 3.128E+06 CPI= 1.372E-12 CMU= 7.201E-13 BETAAC= 1.563E+0
 388 FT= 6.899E+07
 389
 390 NAME: Q54 MODEL: RP0
 391
 392 IB=-2.804E-05 IC=-3.557E-04 VBE=-7.150E-01 VBC= 1.207E+0
 393 VCE=-1.359E+01 BETADC= 1.268E+01 GM= 1.369E-02 RPI= 1.051E+0
 394 RD= 1.968E+05 CPI= 4.986E-12 CMU= 1.845E-13 BETAAC= 1.439E+0
 395 FT= 4.214E+08
 396
 397 NAME: Q55 MODEL: RP1
 398
 399 IB=-3.154E-05 IC=-3.051E-04 VBE=-6.974E-01 VBC= 6.691E-0
 400 VCE=-1.366E+00 BETADC= 9.675E+00 GM= 1.179E-02 RPI= 9.486E+0
 401 RD= 1.905E+05 CPI= 5.744E-12 CMU= 7.404E-13 BETAAC= 1.119E+0
 402 FT= 2.895E+08
 403
 404 NAME: Q56 MODEL: RP1
 405
 406 IB=-1.427E-05 IC=-1.467E-04 VBE=-6.691E-01 VBC= 1.307E+0
 407 VCE=-1.374E+01 BETADC= 1.028E+01 GM= 5.692E-03 RPI= 2.140E+0
 408 RD= 4.828E+05 CPI= 3.109E-12 CMU= 2.596E-13 BETAAC= 1.218E+0
 409 FT= 2.690E+08
 410
 411 NAME: Q57 MODEL: RNO
 412
 413 IB= 1.109E-05 IC= 3.194E-04 VBE= 6.983E-01 VBC=-1.977E+0
 414 VCE= 2.047E+01 BETADC= 2.663E+01 GM= 1.231E-02 RPI= 2.509E+0
 415 RD= 2.844E+05 CPI= 2.171E-12 CMU= 2.486E-13 BETAAC= 3.087E+0
 416 FT= 8.093E+08
 417
 418 NAME: Q58 MODEL: RNO
 419
 420 IB= 2.974E-06 IC= 5.665E-05 VBE= 6.519E-01 VBC=-1.290E+0
 421 VCE= 1.345E+01 BETADC= 1.905E+01 GM= 2.198E-03 RPI= 1.060E+0
 422 RD= 1.502E+06 CPI= 9.723E-13 CMU= 2.688E-13 BETAAC= 2.331E+0
 423 FT= 2.819E+08
 424
 425 NAME: Q59 MODEL: RN1
 426
 427 IB= 3.224E-06 IC= 4.543E-05 VBE= 6.322E-01 VBC=-3.934E-0
 428 VCE= 1.026E+00 BETADC= 1.409E+01 GM= 1.764E-03 RPI= 9.991E+0
 429 RD= 1.605E+06 CPI= 1.512E-12 CMU= 7.275E-13 BETAAC= 1.752E+0
 430 FT= 1.254E+08
 431
 432 NAME: Q60 MODEL: RN1
 433
 434 IB= 1.646E-05 IC= 3.267E-04 VBE= 6.875E-01 VBC=-6.445E-0
 435 VCE= 1.332E+00 BETADC= 1.985E+01 GM= 1.242E-02 RPI= 1.851E+0
 436 RD= 2.209E+05 CPI= 3.165E-12 CMU= 9.405E-13 BETAAC= 2.337E+0
 437 FT= 4.894E+08
 438
 439 NAME: Q61 MODEL: RP0
 440

441 $IB = -2.306E-05$ $IC = -2.861E-04$ $VBE = -7.077E-01$ $VBC = 1.308E+0$
 442 $VCE = -1.378E+01$ $BETADC = 1.240E+01$ $GM = 1.103E-02$ $RPI = 1.245E+0$
 443 $RO = 2.460E+05$ $CPI = 4.139E-12$ $CMU = 1.829E-13$ $BETAAC = 1.417E+0$
 444 $FT = 4.043E+08$
 445
 446 NAME: Q62 MODEL: RN1LC
 447
 448 $IB = 1.245E-05$ $IC = 2.341E-04$ $VBE = 6.777E-01$ $VBC = 0.000E+0$
 449 $VCE = 6.777E-01$ $BETADC = 1.881E+01$ $GM = 9.061E-03$ $RPI = 2.472E+0$
 450 $RO = 3.004E+05$ $CPI = 2.629E-12$ $CMU = 1.047E-12$ $BETAAC = 2.240E+0$
 451 $FT = 3.923E+08$
 452
 453 NAME: Q63 MODEL: RP1LC
 454
 455 $IB = -2.414E-05$ $IC = -2.223E-04$ $VBE = -6.875E-01$ $VBC = 0.000E+0$
 456 $VCE = -6.875E-01$ $BETADC = 9.208E+00$ $GM = 8.605E-03$ $RPI = 1.248E+0$
 457 $RO = 2.600E+05$ $CPI = 4.582E-12$ $CMU = 1.053E-12$ $BETAAC = 1.074E+0$
 458 $FT = 2.430E+08$
 459
 460 NAME: Q64 MODEL: RN1
 461
 462 $IB = 4.662E-06$ $IC = 8.438E-05$ $VBE = 6.445E-01$ $VBC = -1.320E+0$
 463 $VCE = 1.384E+01$ $BETADC = 1.810E+01$ $GM = 3.276E-03$ $RPI = 6.823E+0$
 464 $RO = 1.014E+06$ $CPI = 1.672E-12$ $CMU = 3.956E-13$ $BETAAC = 2.235E+0$
 465 $FT = 2.522E+08$
 466
 467 NAME: Q65 MODEL: RN1
 468
 469 $IB = 1.417E-05$ $IC = 3.197E-04$ $VBE = 6.822E-01$ $VBC = -1.275E+0$
 470 $VCE = 1.343E+01$ $BETADC = 2.256E+01$ $GM = 1.237E-02$ $RPI = 2.161E+0$
 471 $RO = 2.637E+05$ $CPI = 2.857E-12$ $CMU = 4.028E-13$ $BETAAC = 2.672E+0$
 472 $FT = 6.037E+08$
 473
 474 NAME: Q66 MODEL: RN1LC
 475
 476 $IB = 1.655E-05$ $IC = 3.173E-04$ $VBE = 6.870E-01$ $VBC = 0.000E+0$
 477 $VCE = 6.870E-01$ $BETADC = 1.917E+01$ $GM = 1.227E-02$ $RPI = 1.889E+0$
 478 $RO = 5.297E+04$ $CPI = 3.121E-12$ $CMU = 2.252E-12$ $BETAAC = 2.319E+0$
 479 $FT = 3.636E+08$
 480
 481 NAME: Q67 MODEL: RN8C
 482
 483 $IB = 3.956E-05$ $IC = 7.352E-04$ $VBE = 6.486E-01$ $VBC = -1.430E+0$
 484 $VCE = 1.495E+01$ $BETADC = 1.858E+01$ $GM = 2.854E-02$ $RPI = 8.025E+0$
 485 $RO = 1.179E+05$ $CPI = 1.307E-11$ $CMU = 1.848E-12$ $BETAAC = 2.290E+0$
 486 $FT = 3.044E+08$
 487
 488 NAME: Q68 MODEL: RP8C
 489
 490 $IB = -7.312E-05$ $IC = -7.027E-04$ $VBE = -6.545E-01$ $VBC = 1.427E+0$
 491 $VCE = -1.492E+01$ $BETADC = 9.611E+00$ $GM = 2.728E-02$ $RPI = 4.226E+0$
 492 $RO = 1.027E+05$ $CPI = 1.873E-11$ $CMU = 1.171E-12$ $BETAAC = 1.153E+0$
 493 $FT = 2.182E+08$
 494
 495 NAME: Q69 MODEL: RN1LC

496
497 IR= 9.063E-06 IC= 1.605E-04 VBE= 6.668E-01 VBC= 0.000E+0
498 VCE= 6.668E-01 BETADC= 1.771E+01 GM= 6.220E-03 RPI= 3.430E+0
499 RO= 4.500E+05 CPI= 2.198E-12 CMU= 9.432E-13 BETAAC= 2.134E+0
500 FT= 3.151E+08
501
502 NAME: Q70 MODEL: RN1LC
503
504 IR= 9.063E-06 IC= 1.605E-04 VBE= 6.668E-01 VBC= 0.000E+0
505 VCE= 6.668E-01 BETADC= 1.771E+01 GM= 6.219E-03 RPI= 3.431E+0
506 RO= 4.500E+05 CPI= 2.198E-12 CMU= 9.432E-13 BETAAC= 2.133E+0
507 FT= 3.151E+08
508
509 NAME: Q71 MODEL: RN1LC
510
511 IR= 4.127E-06 IC= 6.148E-05 VBE= 6.404E-01 VBC= 0.000E+0
512 VCE= 6.404E-01 BETADC= 1.490E+01 GM= 2.386E-03 RPI= 7.740E+0
513 RO= 1.179E+06 CPI= 1.611E-12 CMU= 8.403E-13 BETAAC= 1.847E+0
514 FT= 1.549E+08
515
516 NAME: Q72 MODEL: RP1LC
517
518 IR=-9.010E-06 IC=-6.937E-05 VBE=-6.537E-01 VBC= 0.000E+0
519 VCE=-6.537E-01 BETADC= 7.699E+00 GM= 2.692E-03 RPI= 3.431E+0
520 RO= 8.360E+05 CPI= 2.379E-12 CMU= 9.047E-13 BETAAC= 9.236E+0
521 FT= 1.305E+08
522
523 NAME: Q73 MODEL: RNO
524
525 IR=-7.342E-11 IC= 7.369E-11 VBE= 0.000E+00 VBC=-1.210E+0
526 VCE= 1.210E+01 BETADC=-1.004E+00 GM=-1.491E-14 RPI= 8.237E+1
527 RO= 3.885E+13 CPI= 4.500E-13 CMU= 2.708E-13 BETAAC=-1.228E-0
528 FT=-3.292E-03
529
530 NAME: Q74 MODEL: RN1
531
532 IR=-1.815E-10 IC= 1.822E-10 VBE=-1.944E-03 VBC=-1.494E+0
533 VCE= 1.494E+01 BETADC=-1.004E+00 GM=-3.687E-14 RPI= 4.119E+1
534 RO= 1.837E+13 CPI= 8.193E-13 CMU= 3.843E-13 BETAAC=-1.518E-0
535 FT=-4.875E-03
536
537 NAME: Q75 MODEL: RP1
538
539 IR= 1.268E-10 IC=-1.273E-10 VBE=-1.944E-03 VBC= 1.493E+0
540 VCE=-1.493E+01 BETADC=-1.004E+00 GM=-2.445E-14 RPI= 5.725E+1
541 RO= 2.451E+13 CPI= 9.507E-13 CMU= 2.473E-13 BETAAC=-1.400E-0
542 FT=-3.248E-03
543
544 NAME: Q76 MODEL: RP0
545
546 IR= 5.108E-12 IC=-5.124E-12 VBE= 0.000E+00 VBC= 1.202E+0
547 VCE=-1.202E+00 BETADC=-1.003E+00 GM=-1.092E-15 RPI= 1.210E+1
548 RO= 7.058E+13 CPI= 5.200E-13 CMU= 3.670E-13 BETAAC=-1.321E-0
549 FT=-1.959E-04
550

551 NAME: Q77 MODEL: RP1
 552
 553 IB= 1.022E-11 IC=-1.025E-11 VBE= 0.000E+00 VBC= 1.202E+0
 554 VCE=-1.202E+00 BETADC=-1.003E+00 GM=-2.184E-15 RPI= 6.048E+1
 555 RO= 3.529E+13 CPI= 9.500E-13 CMU= 5.260E-13 BETAAC=-1.321E-0
 556 FT=-2.355E-04
 557
 558 NAME: Q78 MODEL: RP0
 559
 560 IB= 5.108E-12 IC=-5.124E-12 VBE= 0.000E+00 VBC= 1.202E+0
 561 VCE=-1.202E+00 BETADC=-1.003E+00 GM=-1.092E-15 RPI= 1.210E+1
 562 RO= 7.058E+13 CPI= 5.200E-13 CMU= 3.670E-13 BETAAC=-1.321E-0
 563 FT=-1.959E-04
 564
 565 NAME: Q79 MODEL: RN1
 566
 567 IB=-1.334E-11 IC= 1.339E-11 VBE= 0.000E+00 VBC=-1.099E+0
 568 VCE= 1.099E+00 BETADC=-1.003E+00 GM=-2.710E-15 RPI= 4.119E+1
 569 RO= 2.496E+13 CPI= 8.200E-13 CMU= 6.211E-13 BETAAC=-1.116E-0
 570 FT=-2.993E-04
 571
 572 NAME: Q80 MODEL: RN1
 573
 574 IB=-1.334E-11 IC= 1.339E-11 VBE= 0.000E+00 VBC=-1.099E+0
 575 VCE= 1.099E+00 BETADC=-1.003E+00 GM=-2.710E-15 RPI= 4.119E+1
 576 RO= 2.496E+13 CPI= 8.200E-13 CMU= 6.211E-13 BETAAC=-1.116E-0
 577 FT=-2.993E-04
 578
 579 NAME: Q81 MODEL: RN1
 580
 581 IB=-1.334E-11 IC= 1.339E-11 VBE= 0.000E+00 VBC=-1.099E+0
 582 VCE= 1.099E+00 BETADC=-1.003E+00 GM=-2.710E-15 RPI= 4.119E+1
 583 RO= 2.496E+13 CPI= 8.200E-13 CMU= 6.211E-13 BETAAC=-1.116E-0
 584 FT=-2.993E-04
 585
 586 NAME: Q82 MODEL: RN1
 587
 588 IB=-1.334E-11 IC= 1.339E-11 VBE= 0.000E+00 VBC=-1.099E+0
 589 VCE= 1.099E+00 BETADC=-1.003E+00 GM=-2.710E-15 RPI= 4.119E+1
 590 RO= 2.496E+13 CPI= 8.200E-13 CMU= 6.211E-13 BETAAC=-1.116E-0
 591 FT=-2.993E-04
 592
 593 NAME: Q83 MODEL: RP0
 594
 595 IB= 6.717E-11 IC=-6.744E-11 VBE= 0.000E+00 VBC= 1.581E+0
 596 VCE=-1.581E+01 BETADC=-1.004E+00 GM=-1.436E-14 RPI= 1.210E+1
 597 RO= 4.807E+13 CPI= 5.200E-13 CMU= 1.694E-13 BETAAC=-1.737E-0
 598 FT=-3.315E-03
 599
 600 NAME: Q84 MODEL: RN8C
 601
 602 IB=-1.326E-10 IC= 1.330E-10 VBE= 0.000E+00 VBC=-1.365E+0
 603 VCE= 1.365E+00 BETADC=-1.003E+00 GM=-2.692E-14 RPI= 5.148E+1
 604 RO= 3.099E+12 CPI= 6.200E-12 CMU= 2.855E-12 BETAAC=-1.386E-0
 605 FT=-4.732E-04

506
507 NAME: Q85 MODEL: RNO
608
509 IR=-1.301E-11 IC= 1.306E-11 VBF= 0.000E+00 VBC=-2.145E+00
510 VCE= 2.145E+00 BETADCE=-1.003E+00 GME=-2.643E-15 RPI= 8.237E+11
611 RO= 4.860E+13 CPI= 4.500E-15 CMII= 3.766E-13 BETAAC=-2.177E-03
512 FT=-5.089E-04

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APPENDIX 3.0

AC and TRANSIENT SIMULATIONS

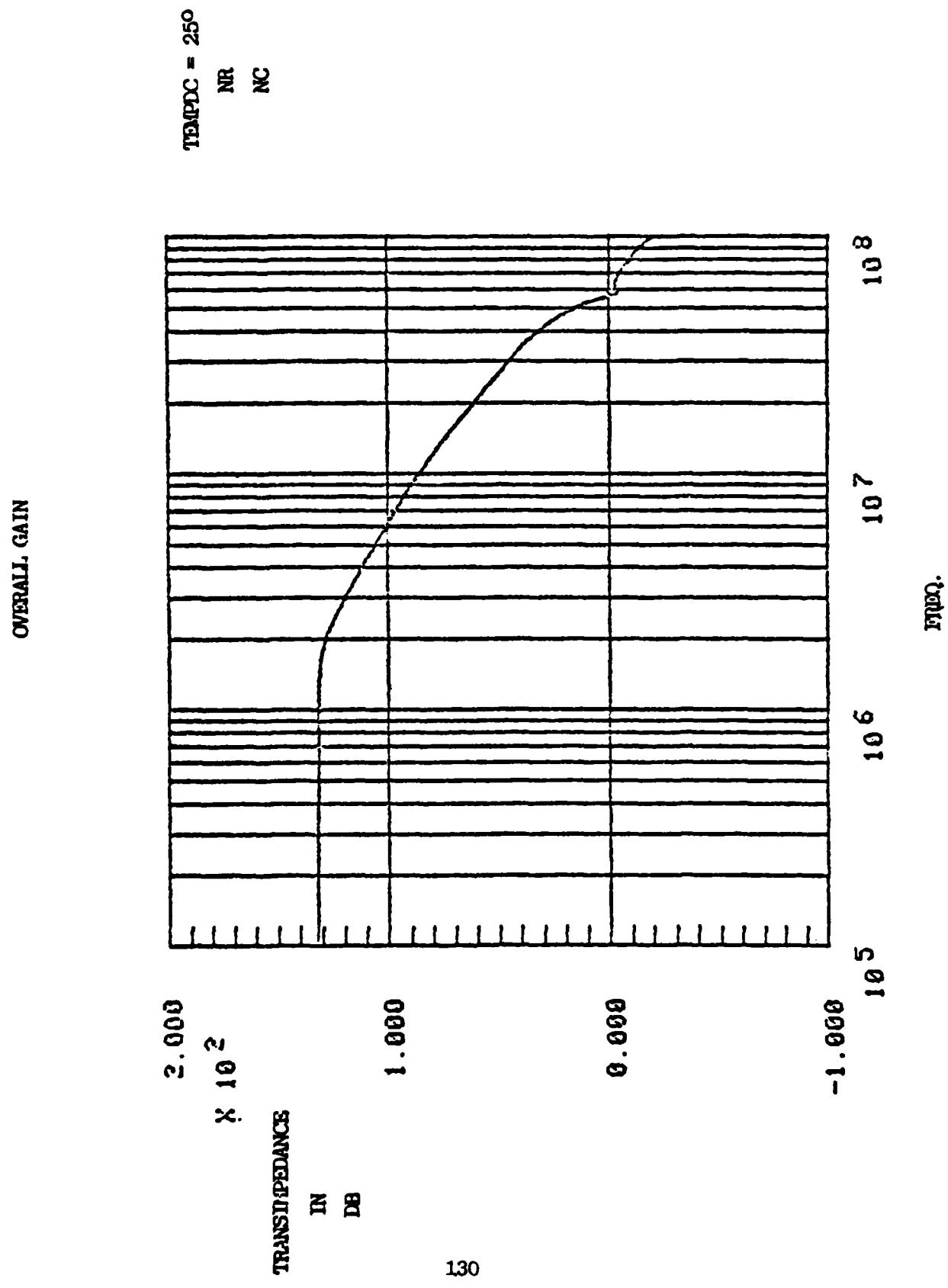
- 3.1 25° AC and Step Response
- 3.2 125° " " "
- 3.3 -55° " " "
- 3.4 25° Post-Neutron AC and Step Responses

Key: Abbreviations for Process Variation

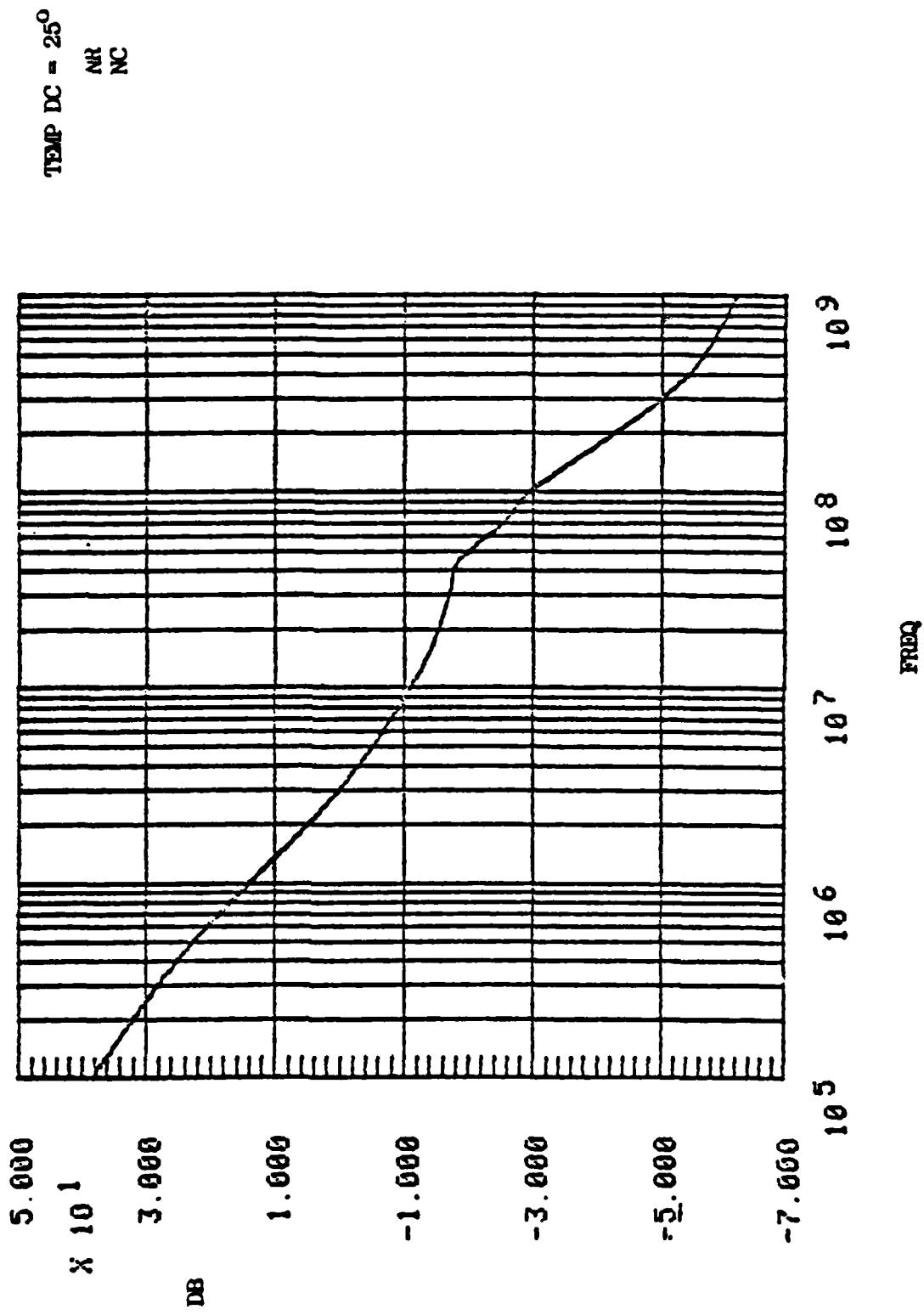
NR, NC: Nominal Resistors
Nominal Capacitors

HR, HC: 10% High Resistors
10% High Capacitors

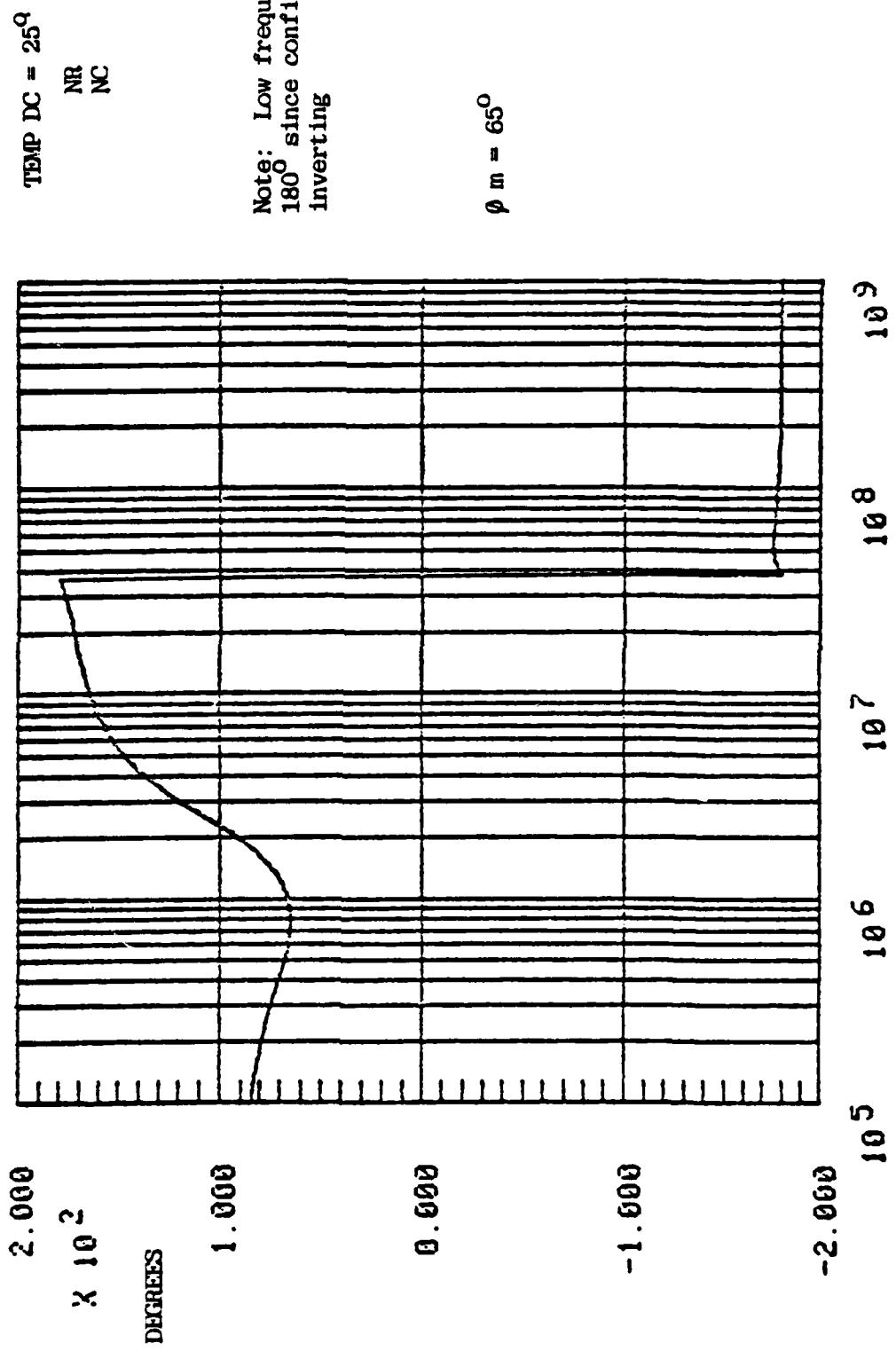
LR, LC: 10% Low Resistors
10% Low Capacitors



A₁ OPEN-LOOP GAIN

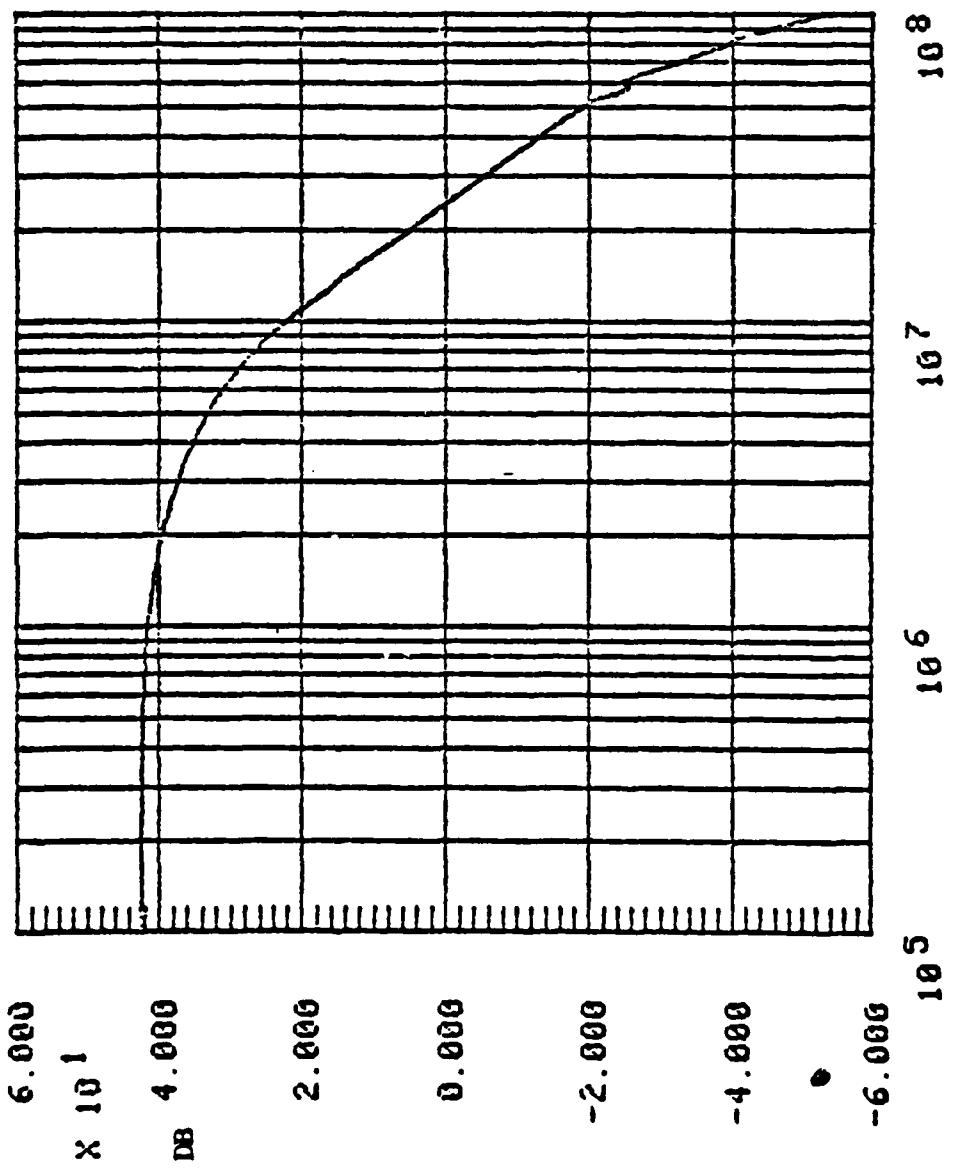


A_1 OPEN-LOOP PHASE

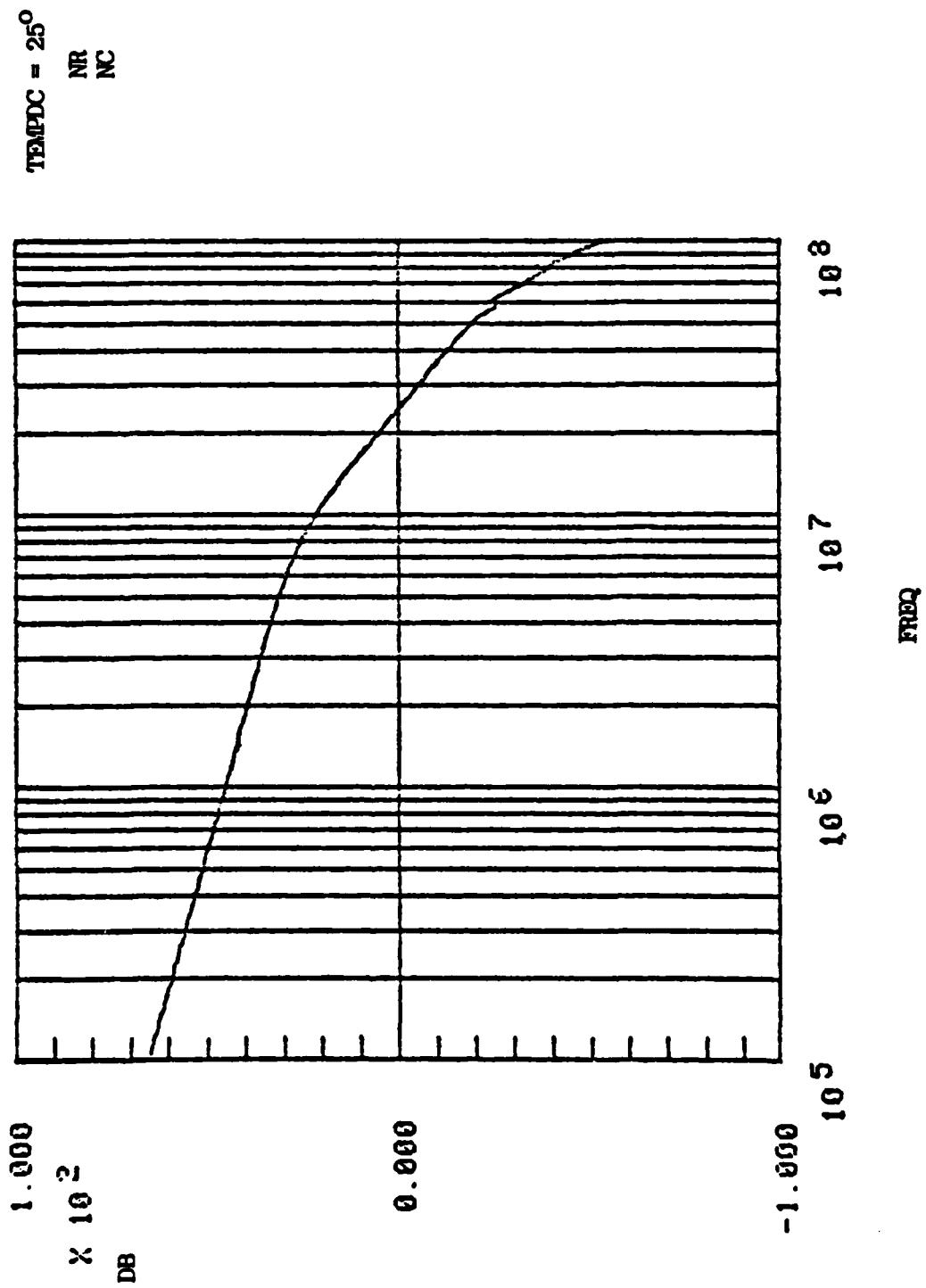


A_2 CLOSED-LOOP GAIN

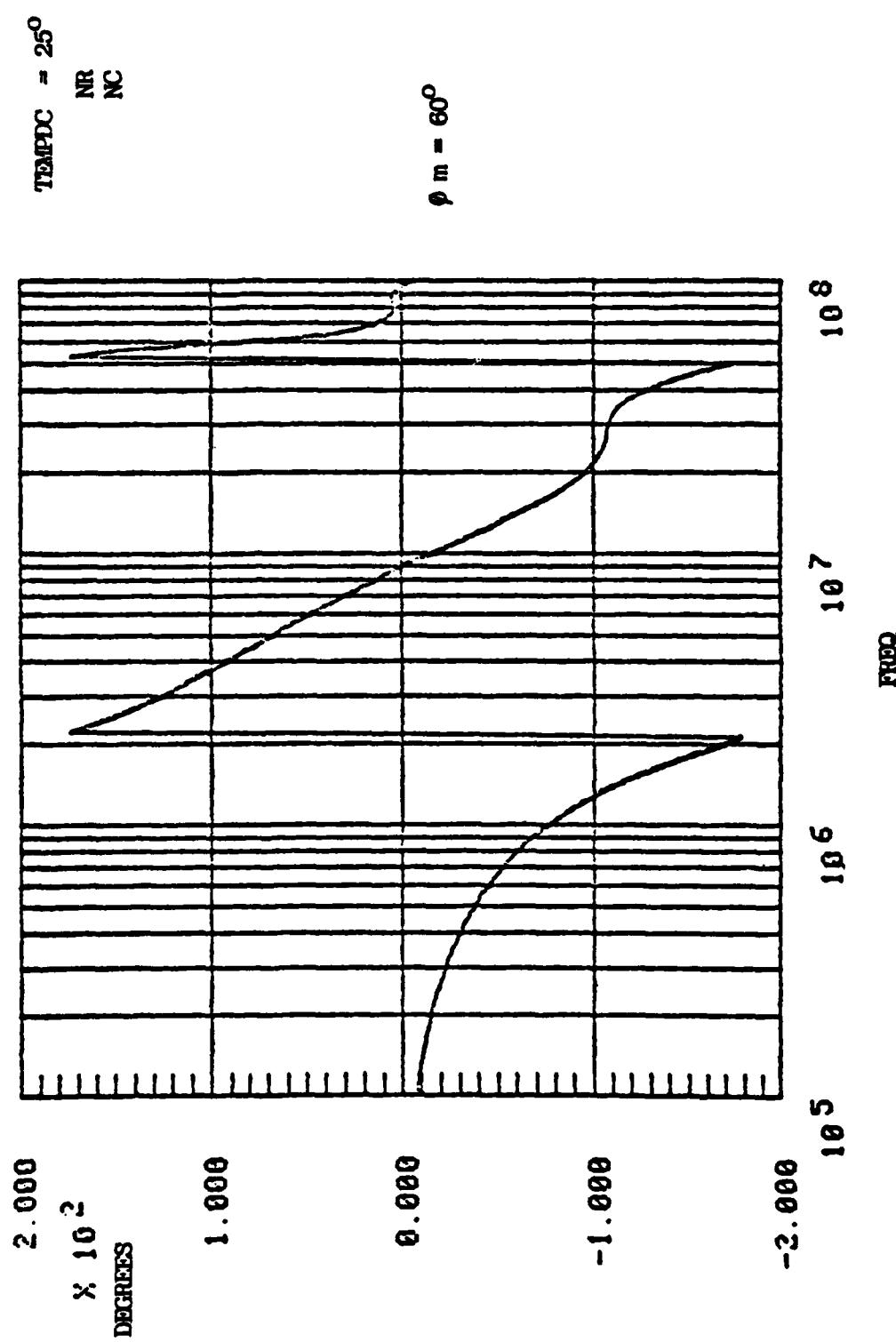
TEMPDC = 25°
NC
NR



A_2 OPEN-LOOP GAIN

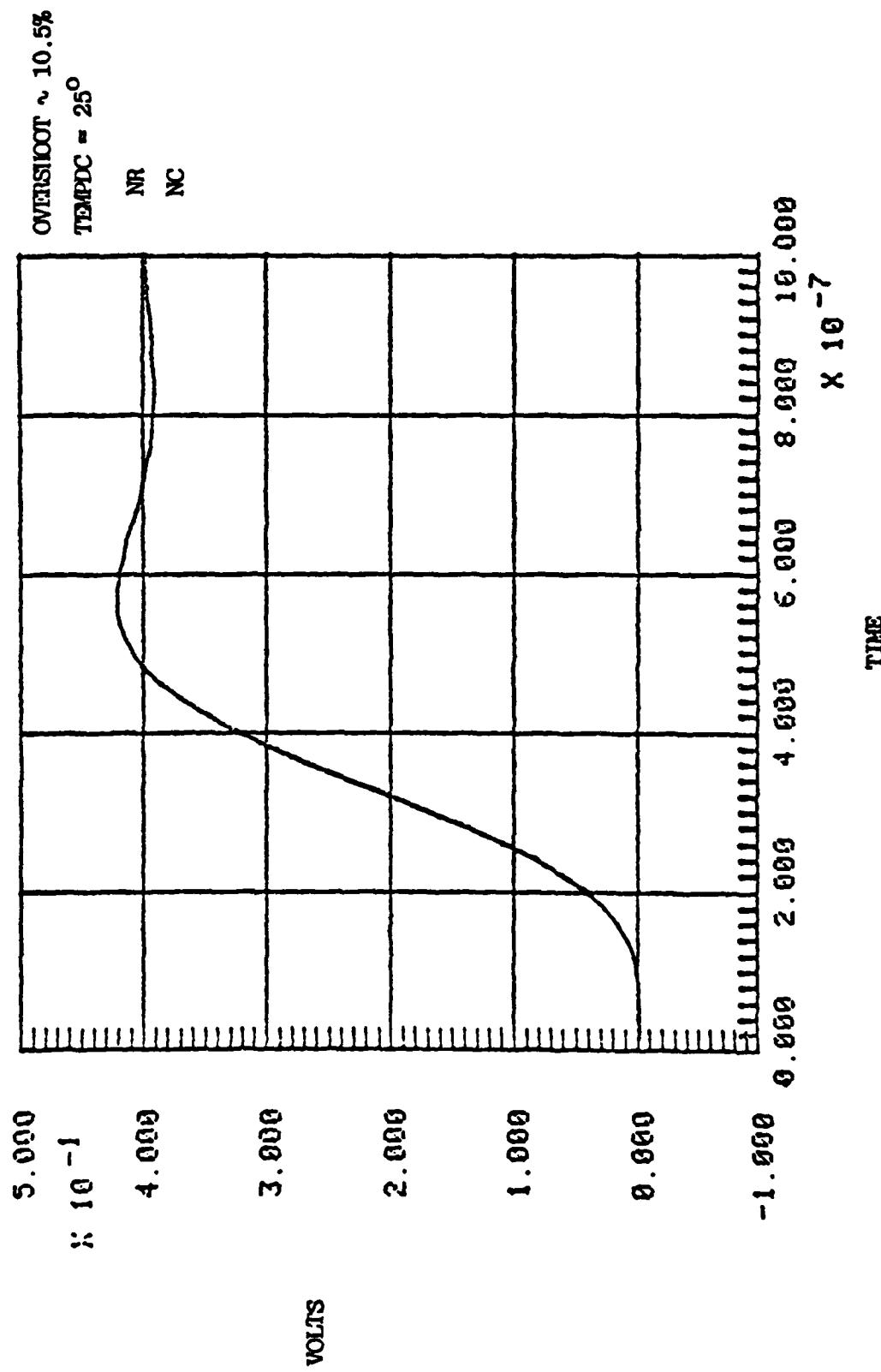


A_2 OPEN-LOOP PHASE

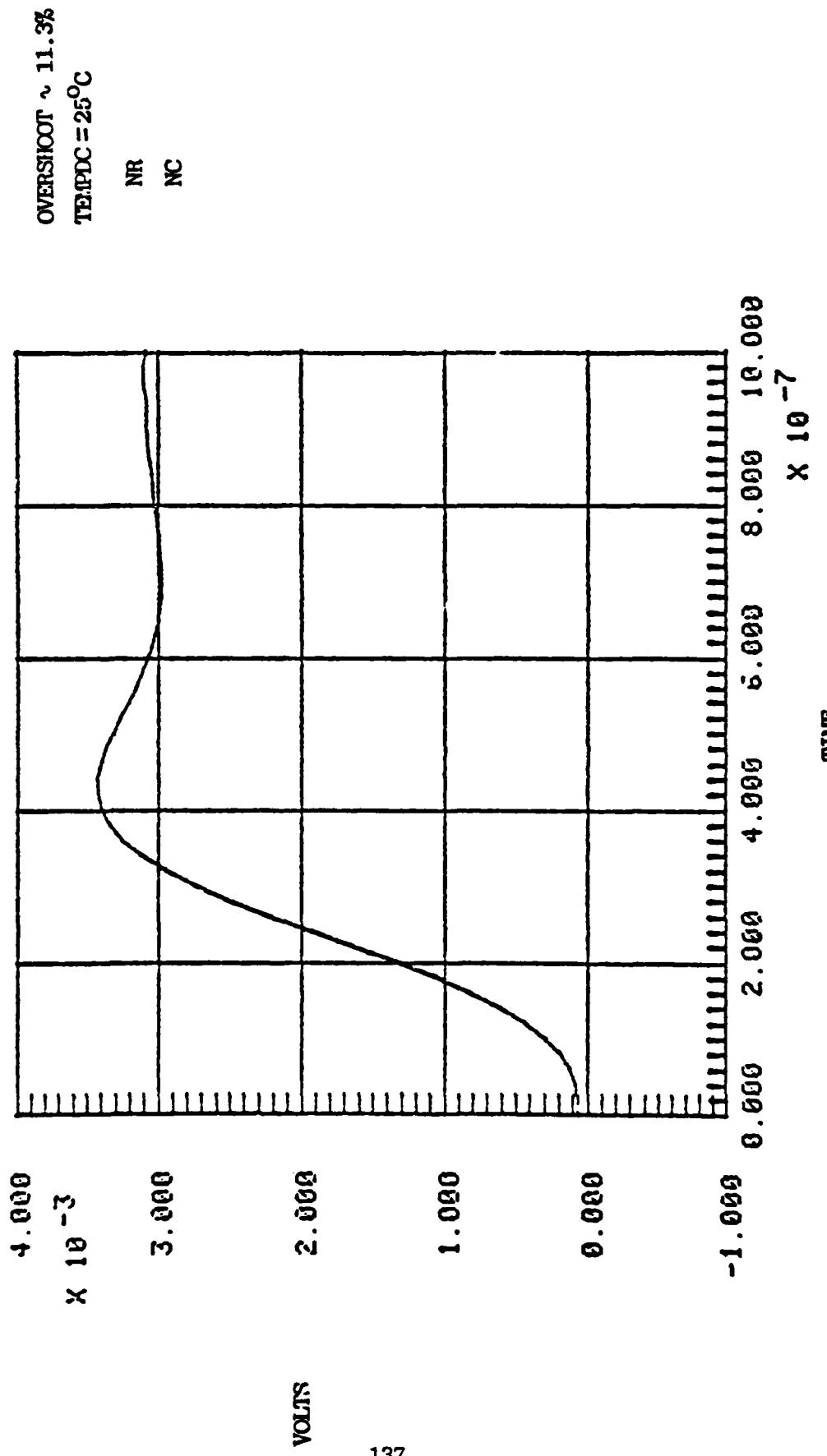


OVERALL STEP RESPONSE

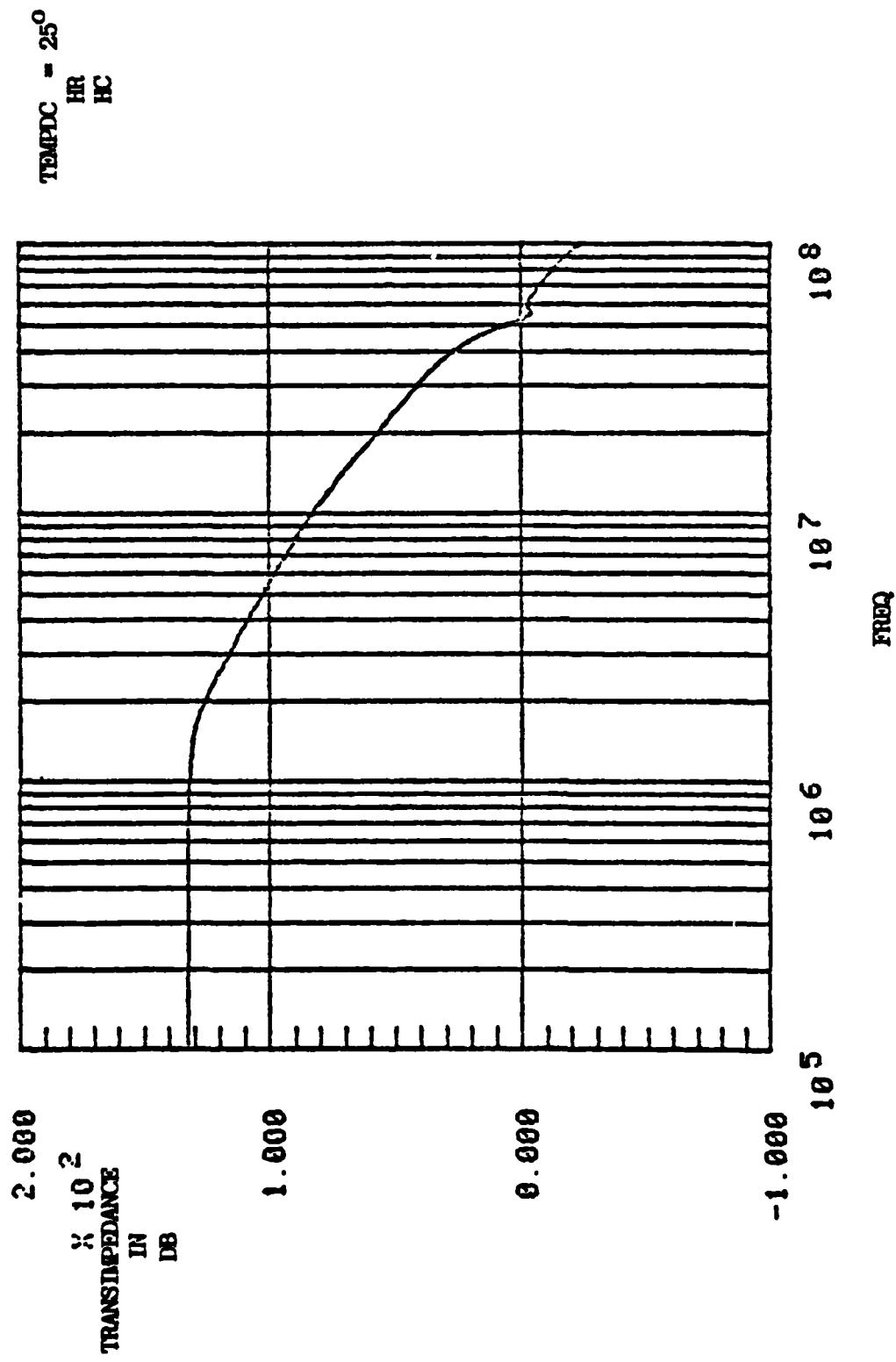
100 mA STEP

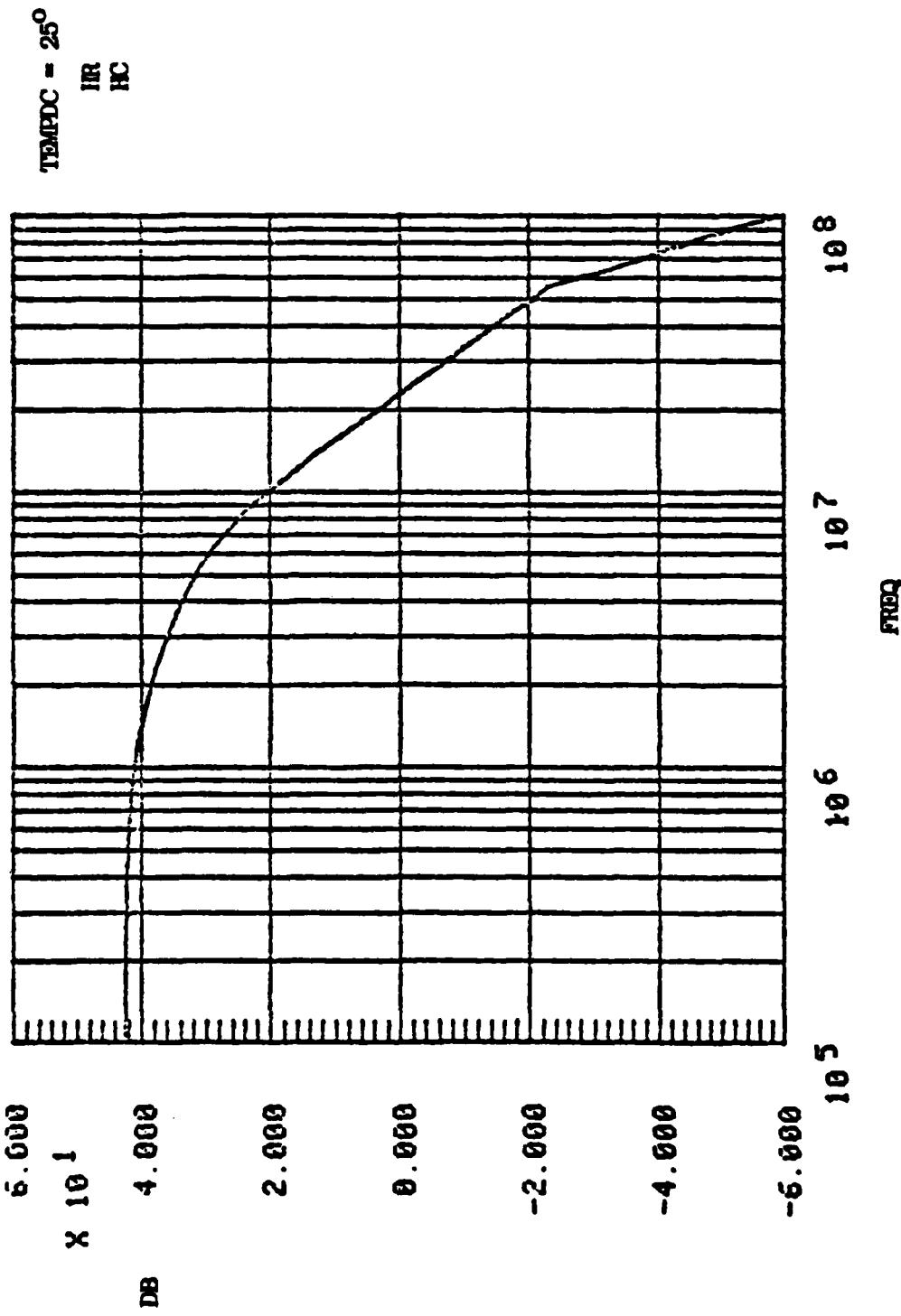


A_1 STEP RESPONSE
100 NA STEP

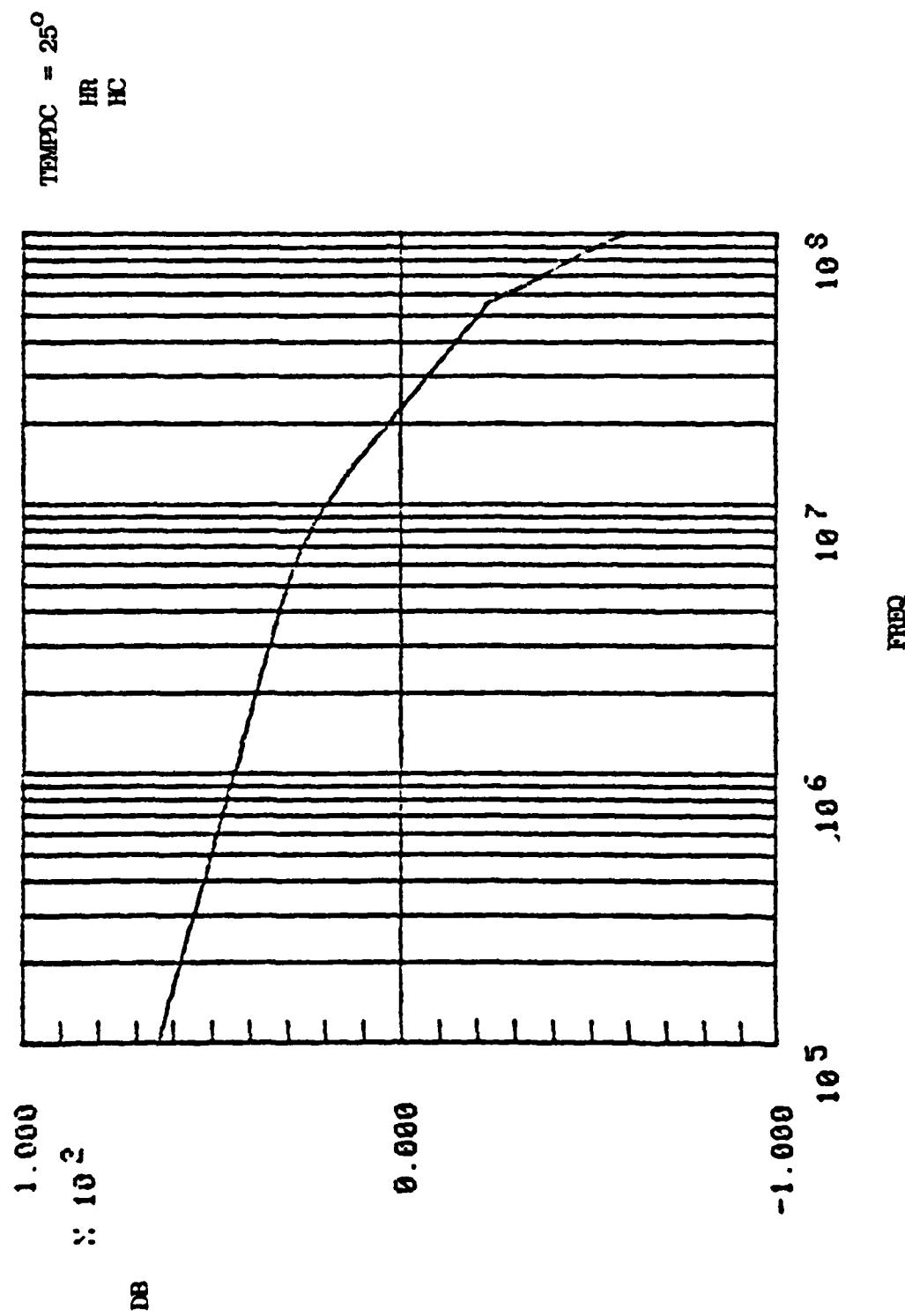


OVERALL GAIN

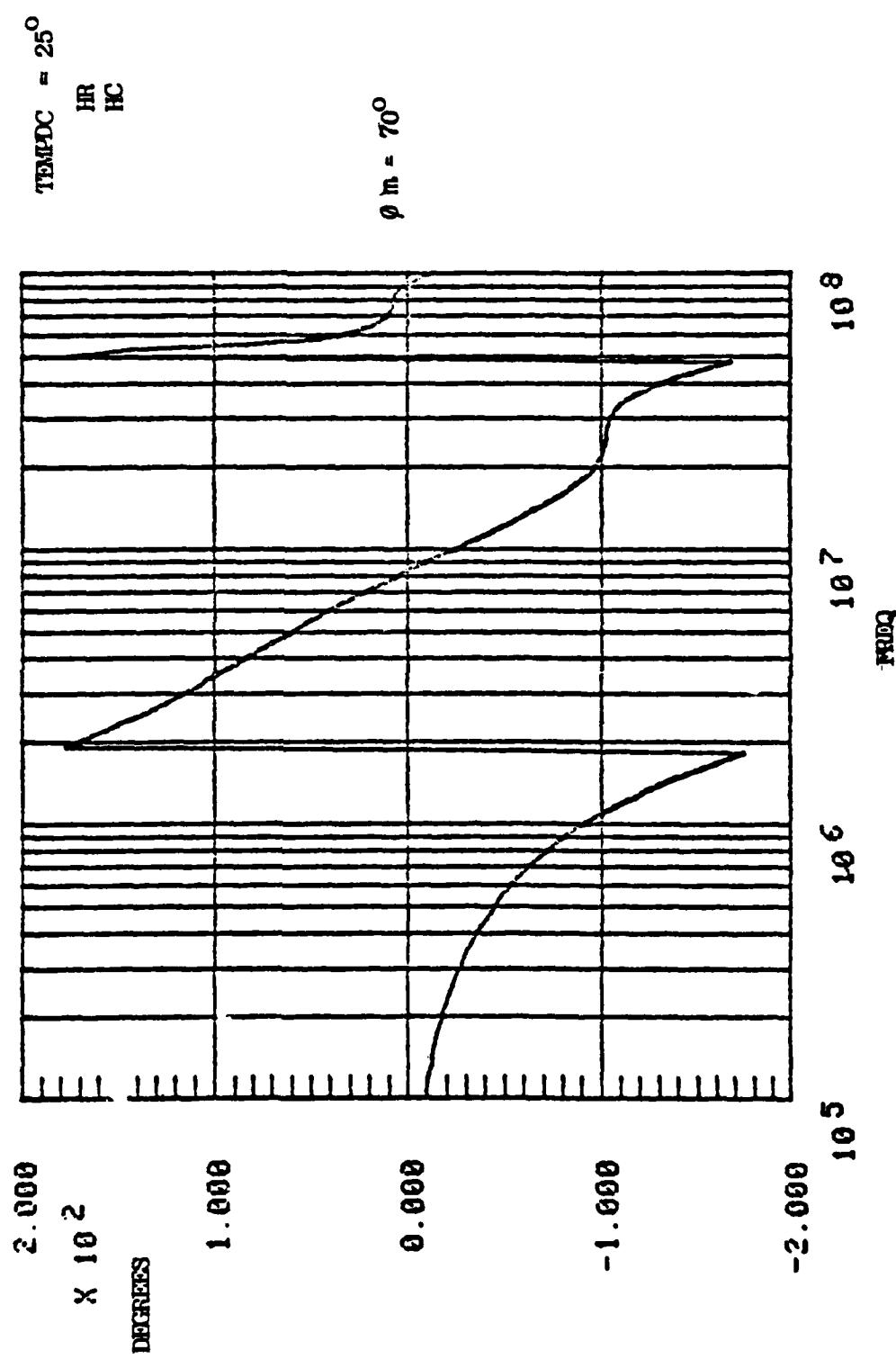


A_2 OPEN-LOOP GAIN

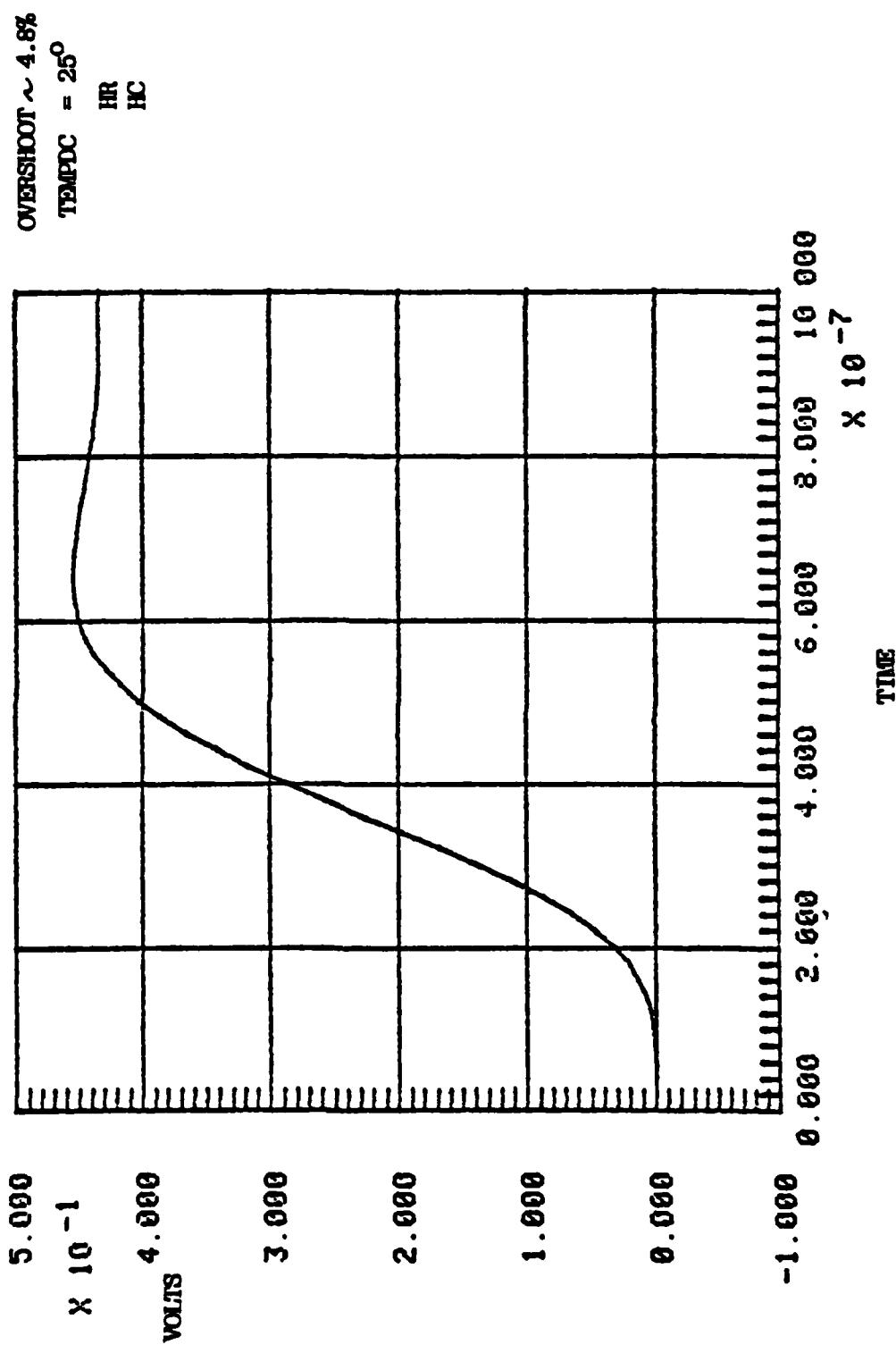
A_2 OPEN-LOOP GAIN



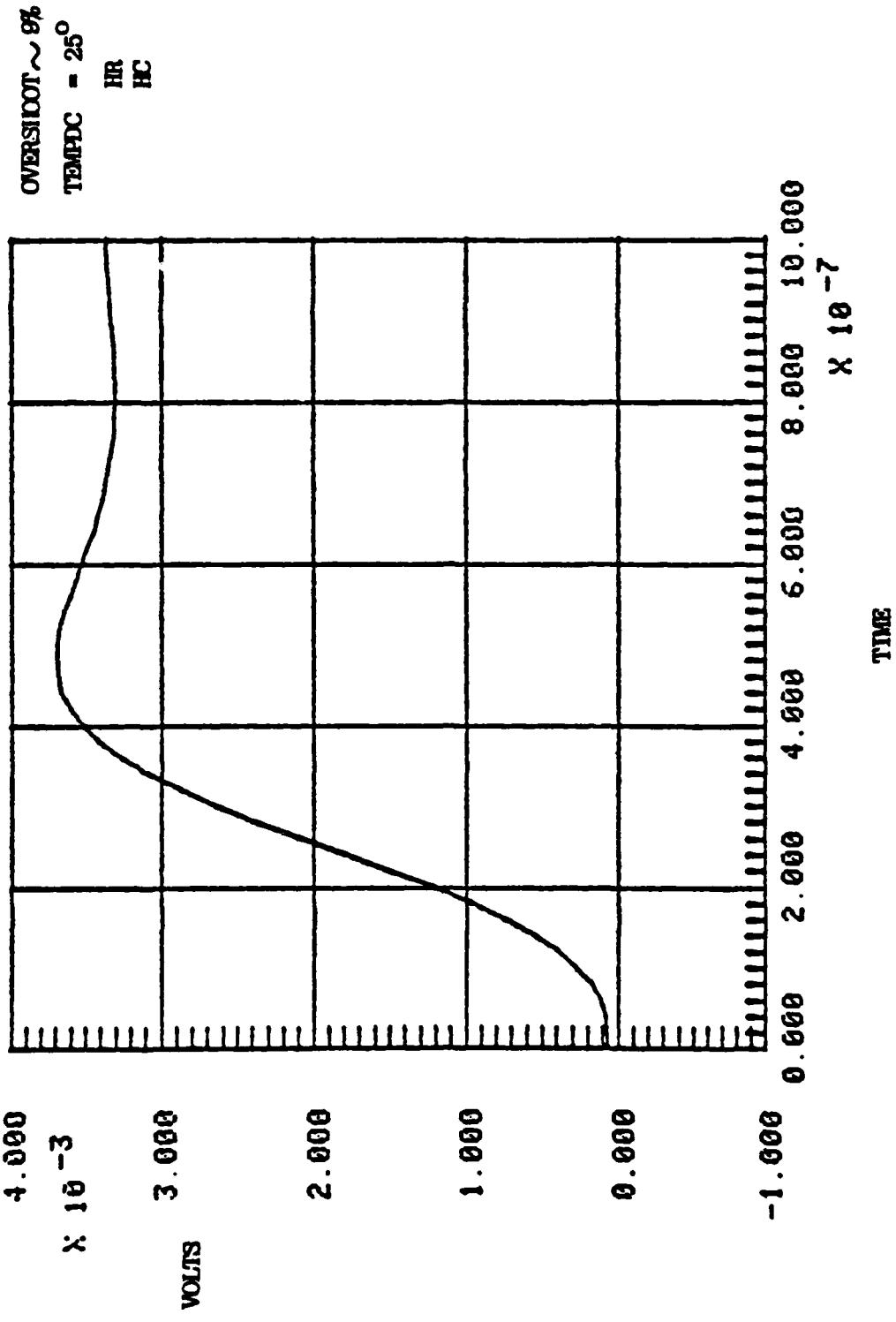
A_2 OPEN-LOOP PHASE



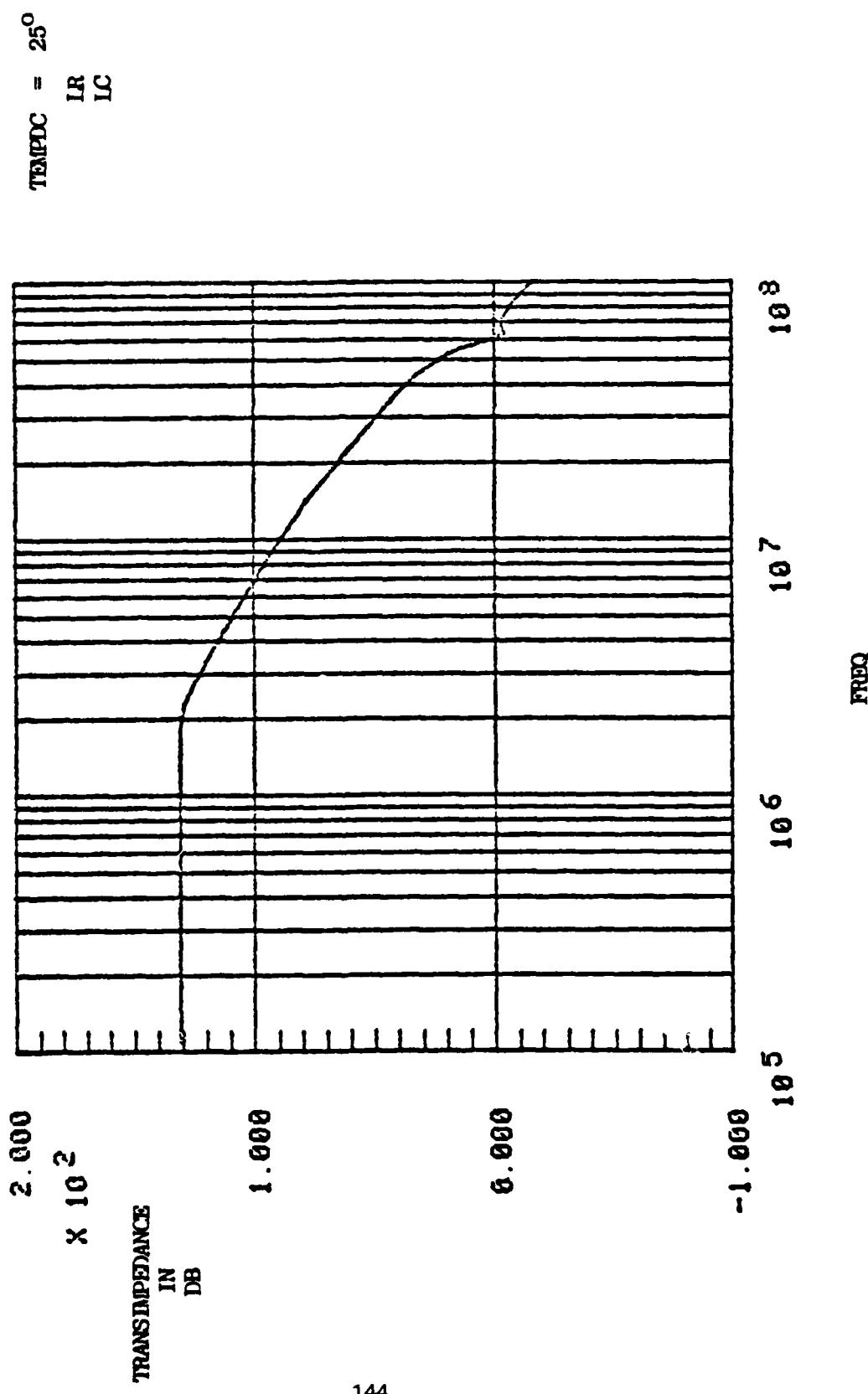
OVERALL STEP RESPONSE
100 mA STEP



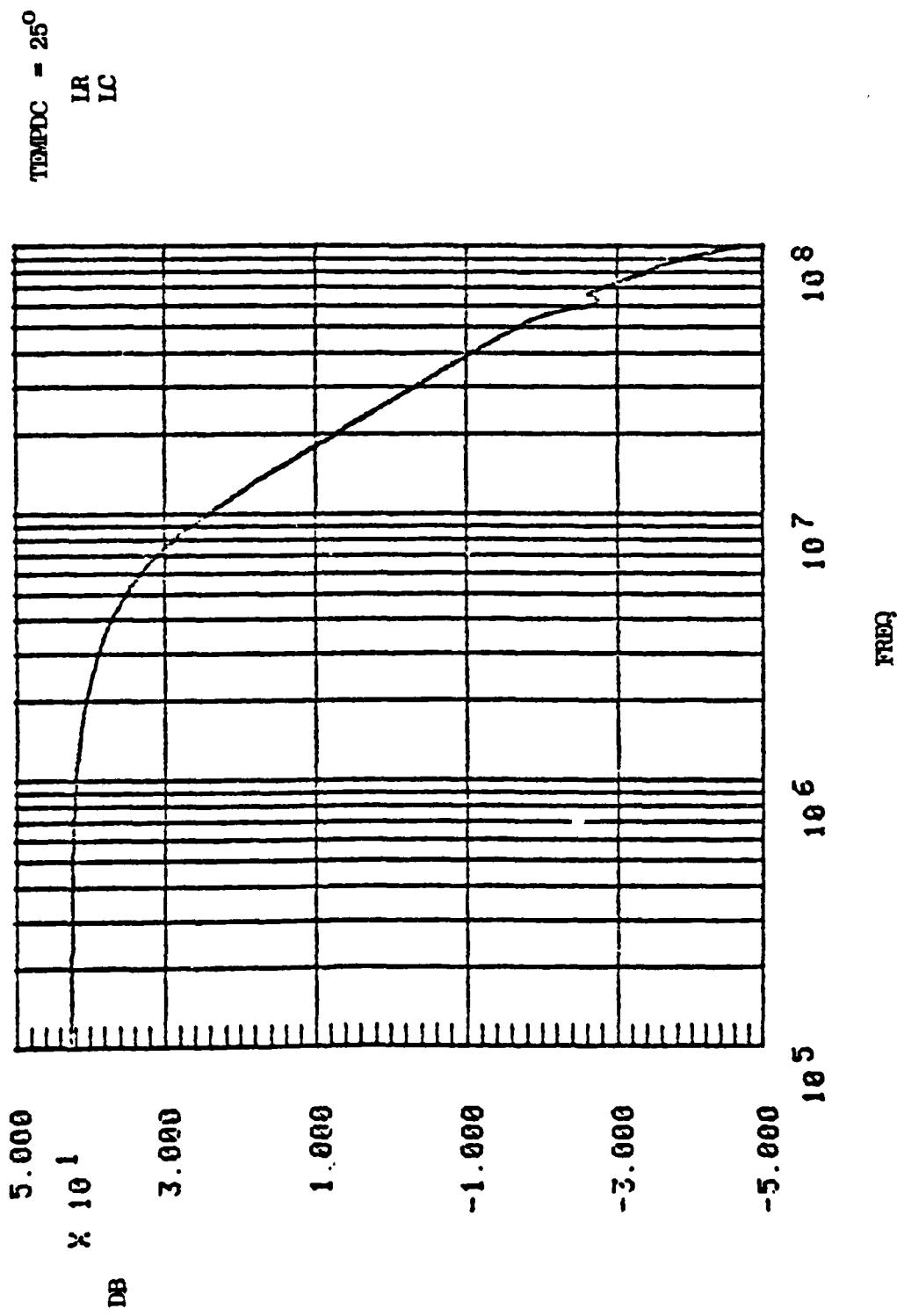
A_1 STEP RESPONSE
100 nA Step



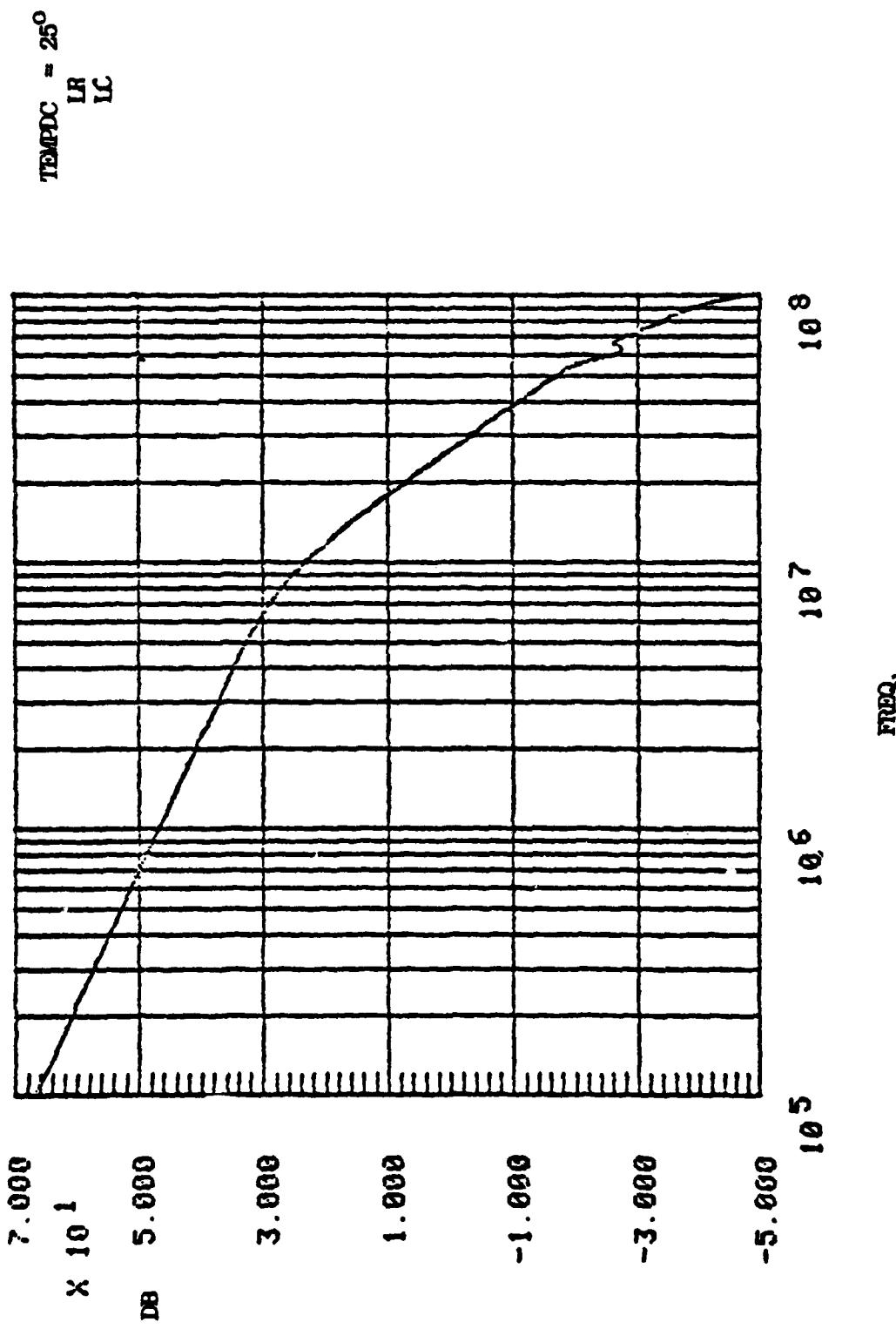
OVERALL GAIN



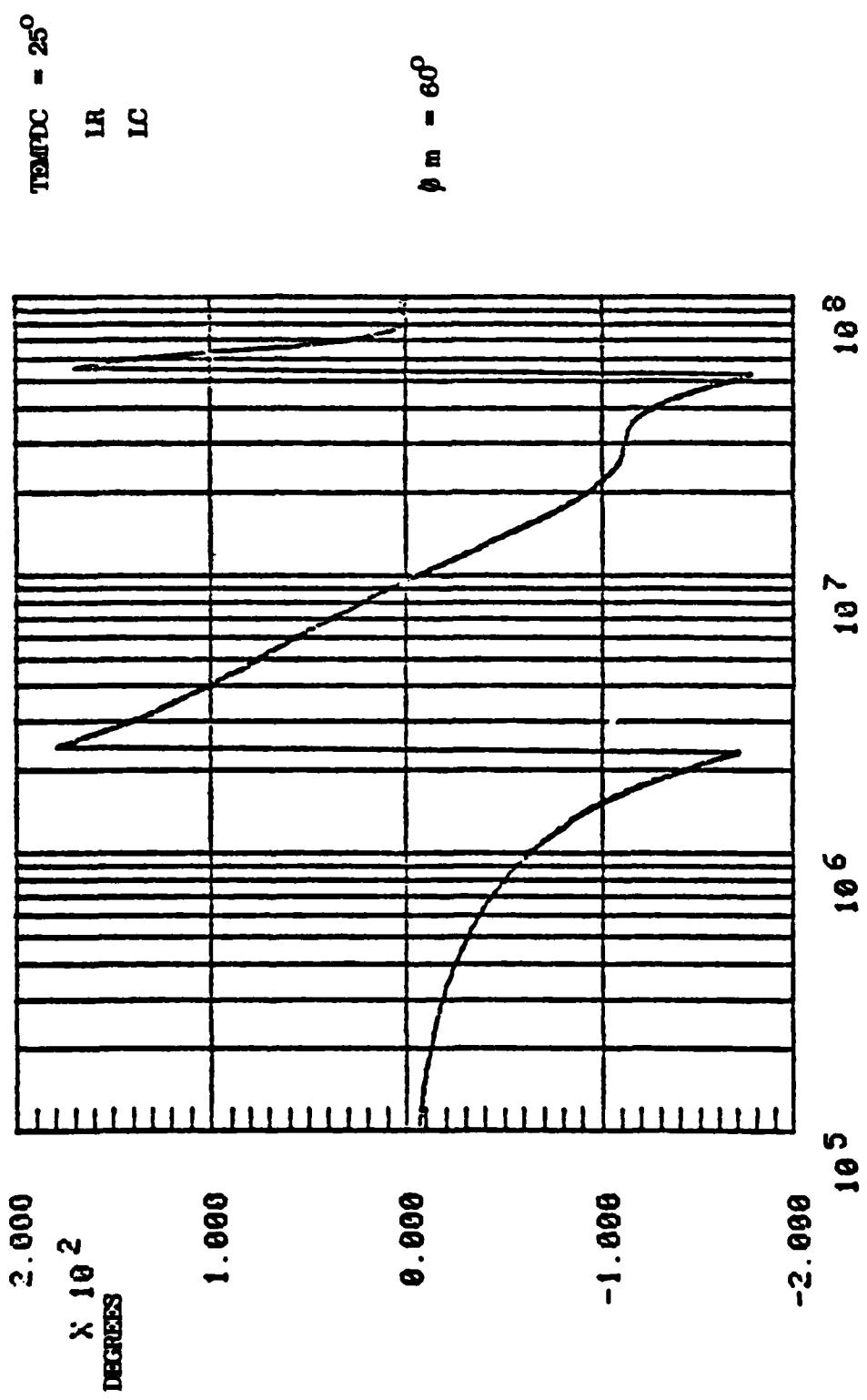
A_2 CLOSED-LOOP GAIN



A_2 OPEN-LOOP GAIN

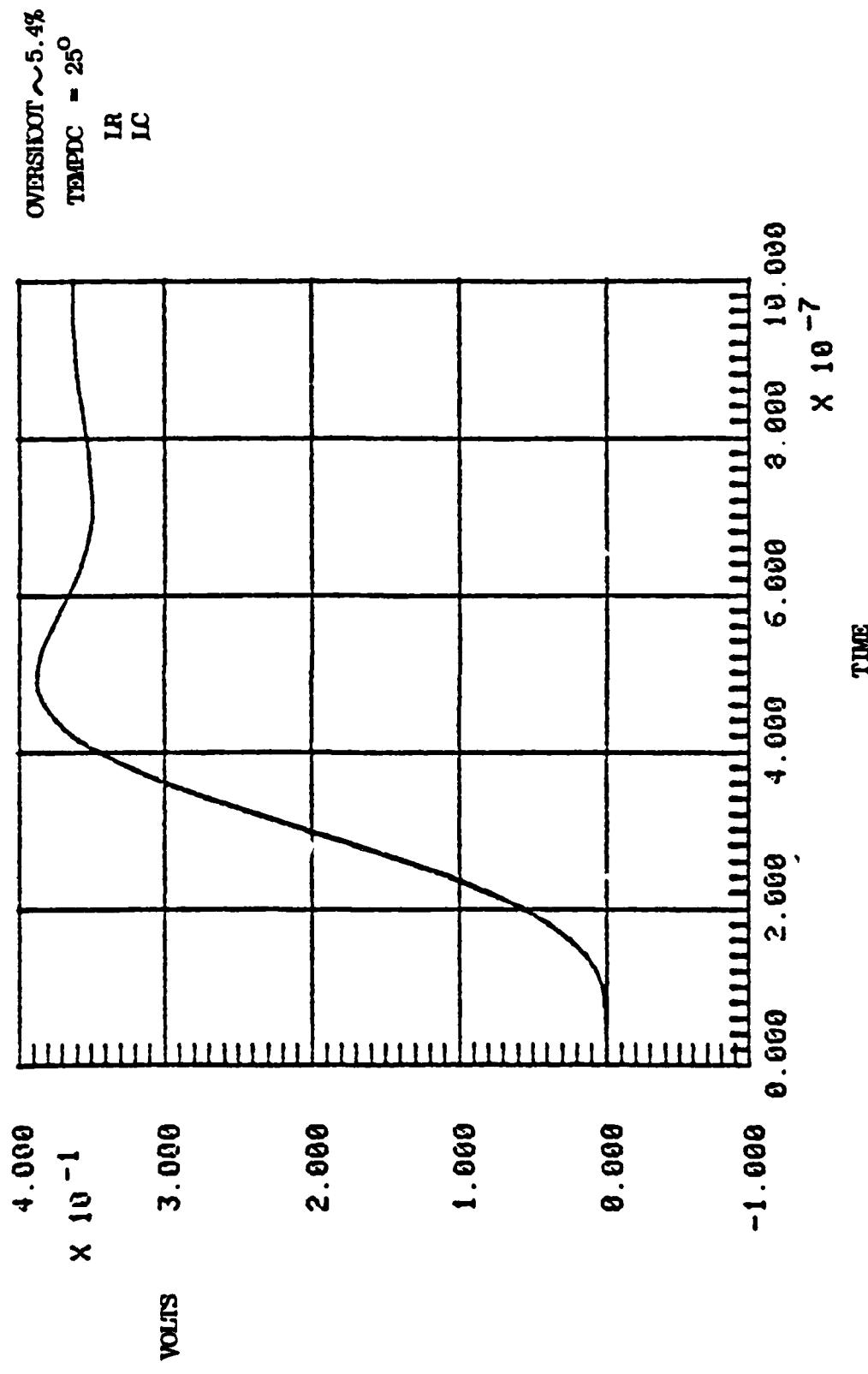


A_2 OPEN-LOOP PHASE

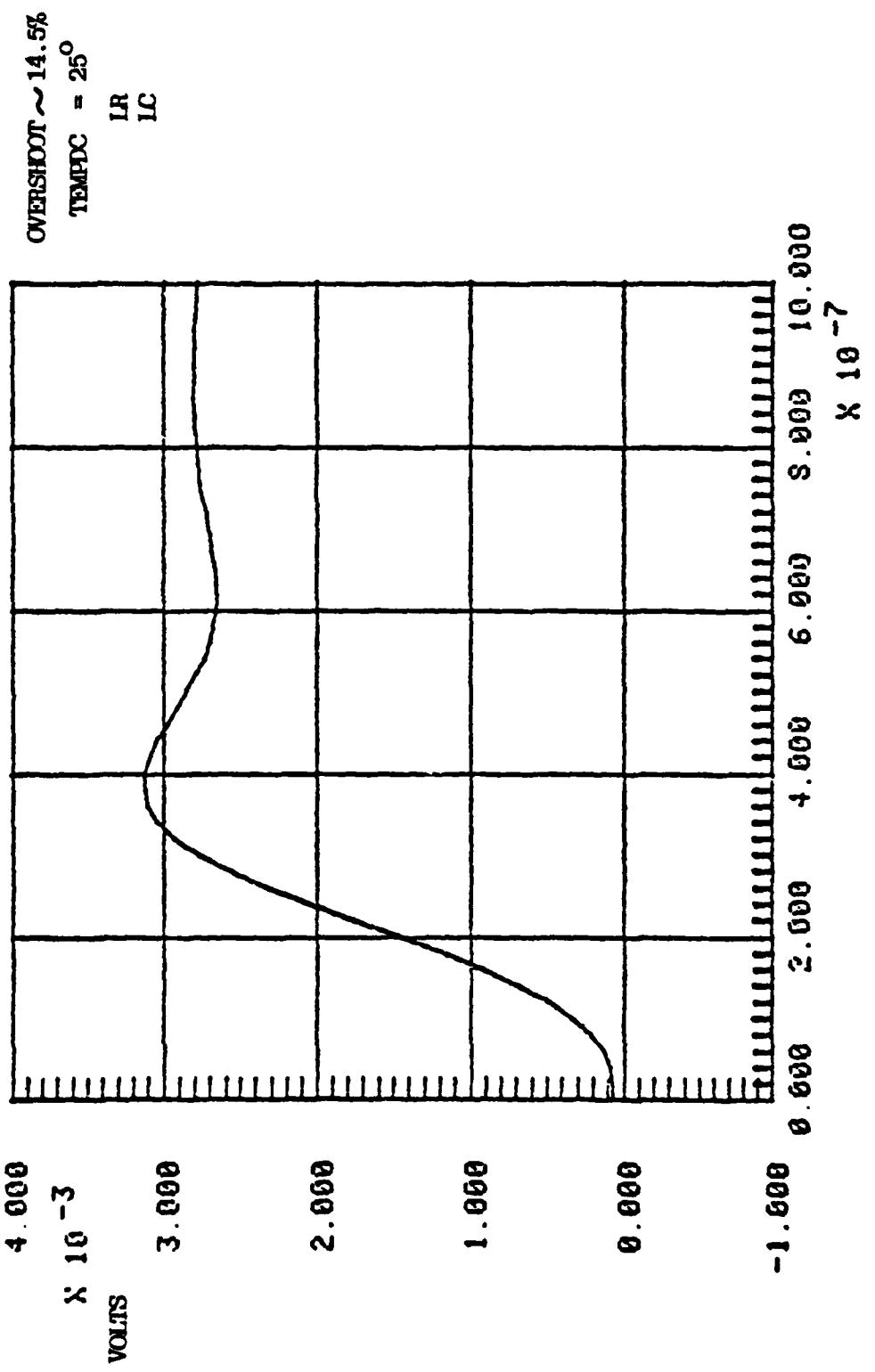


OVERALL STEP RESPONSE

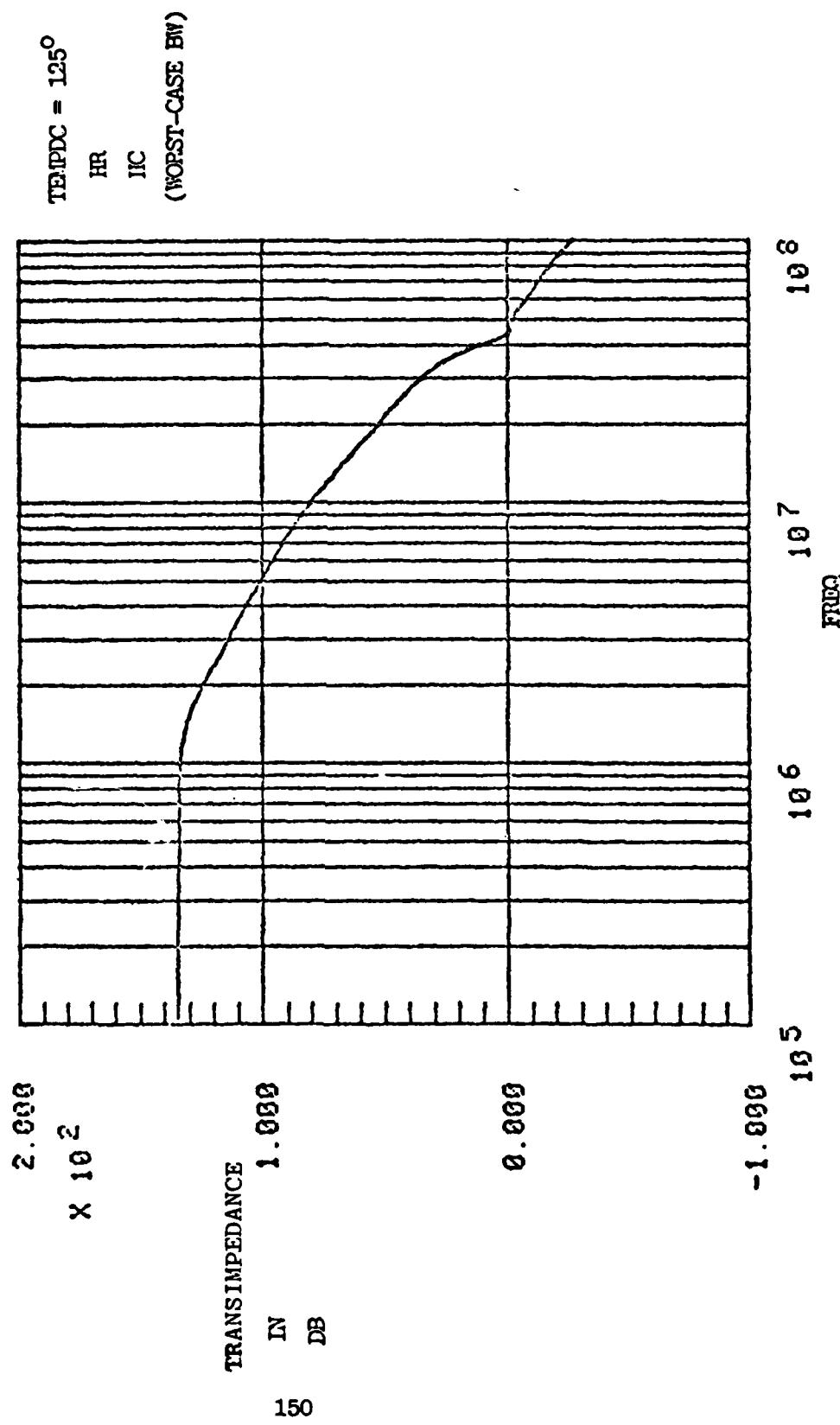
100 nA STEP



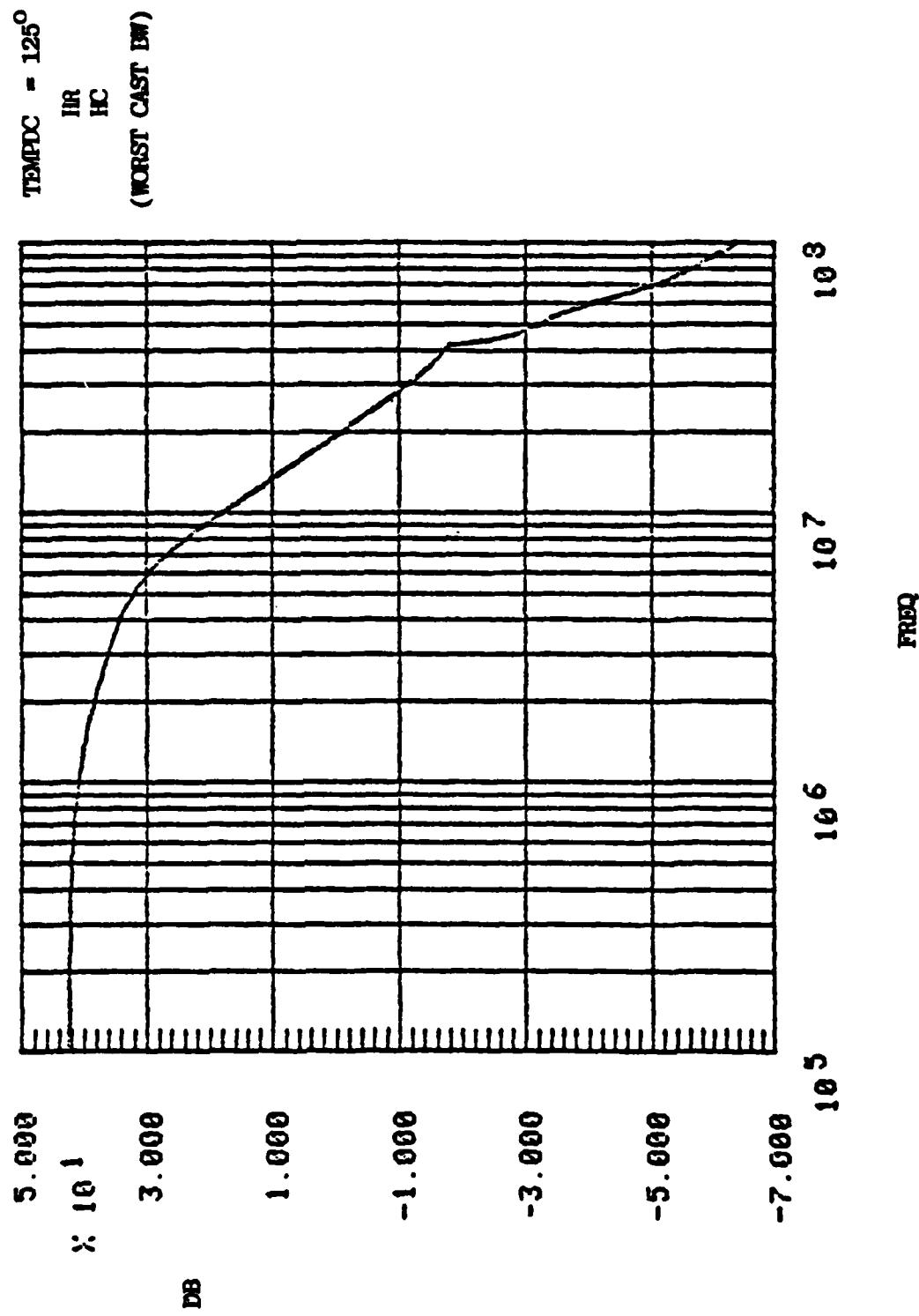
A_1 STEP RESPONSE
100 nA STEP



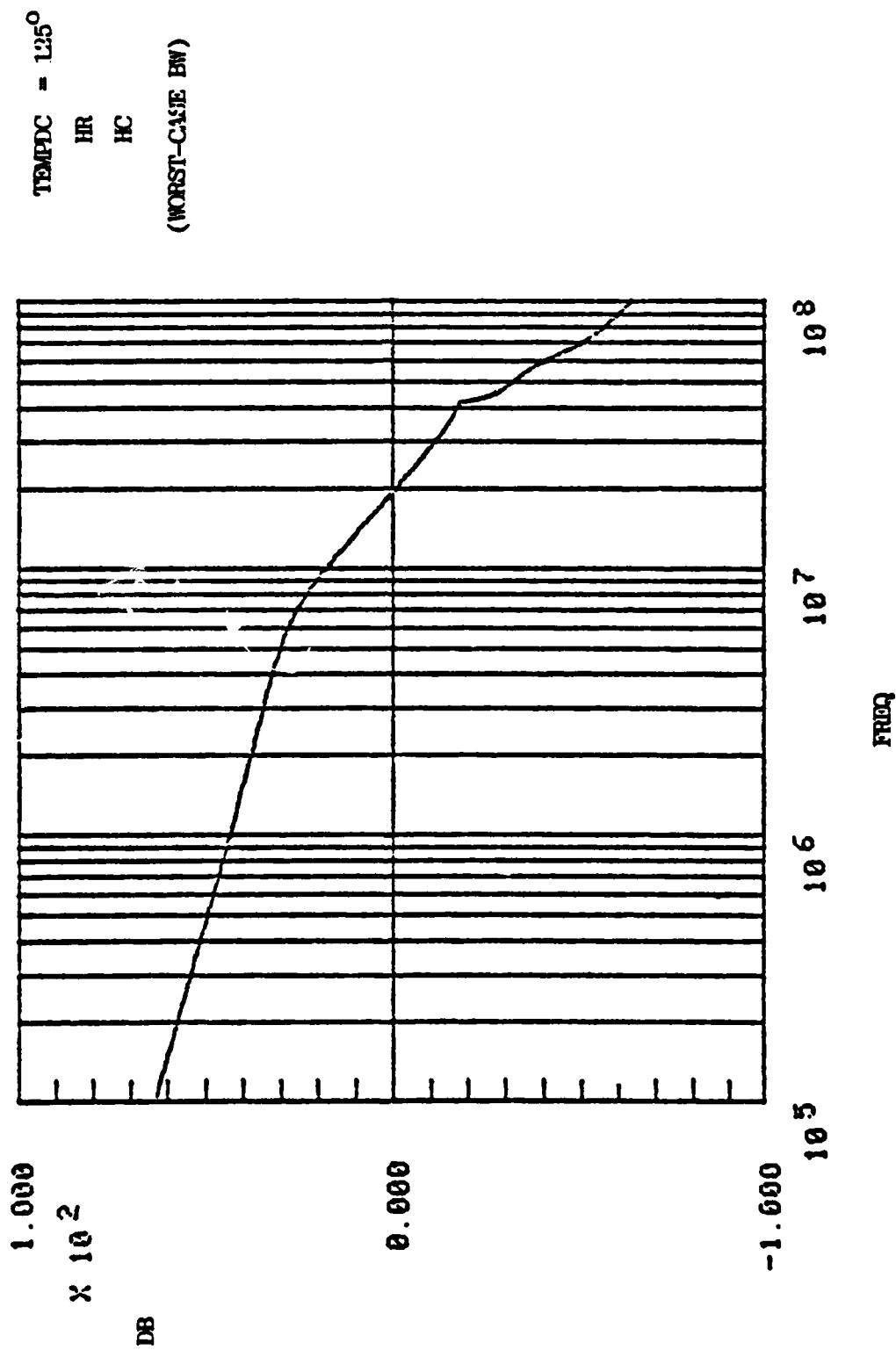
OVERALL GAIN



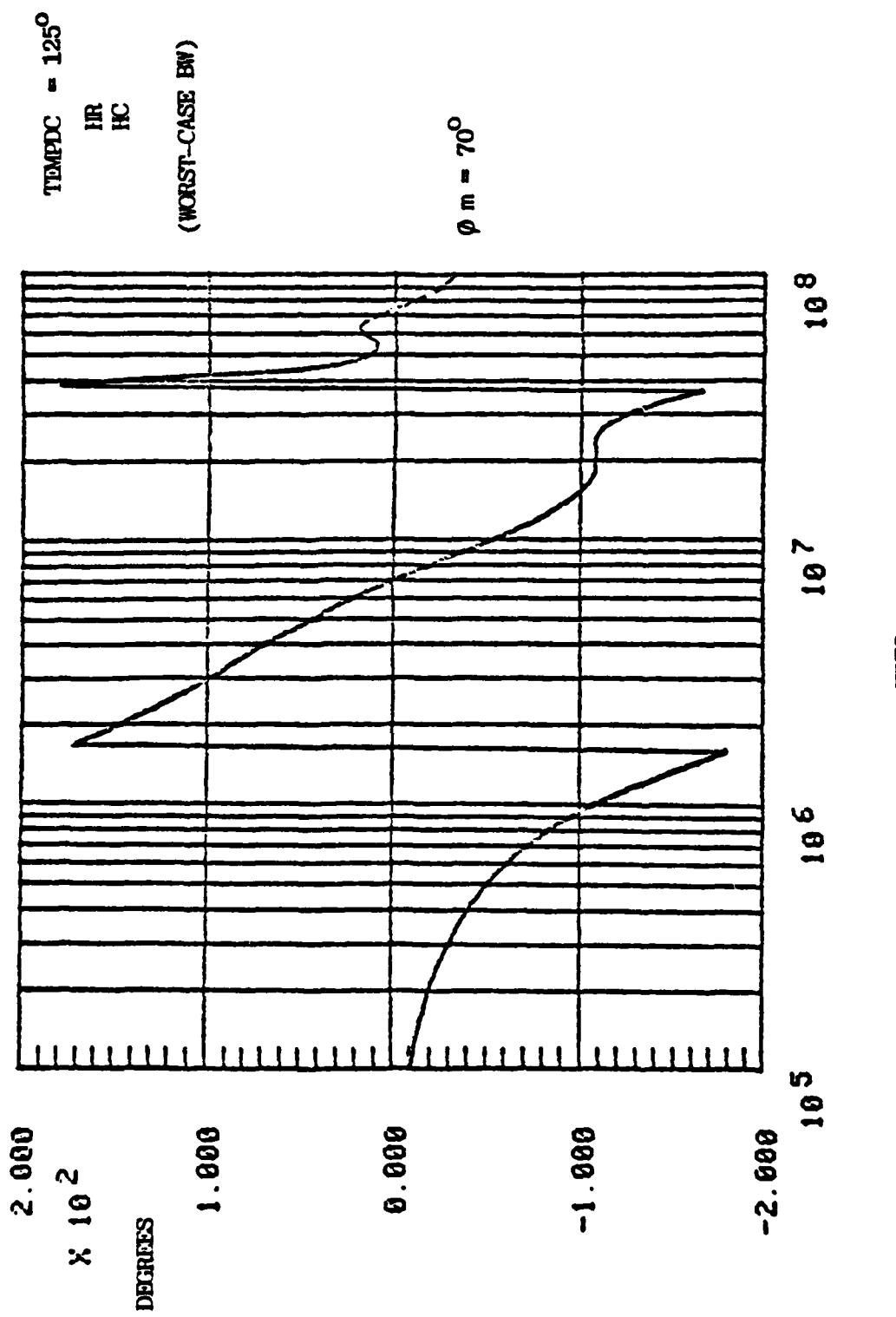
A_2 CLOSED-LOOP GAIN



A_2 OPEN-LOOP GAIN

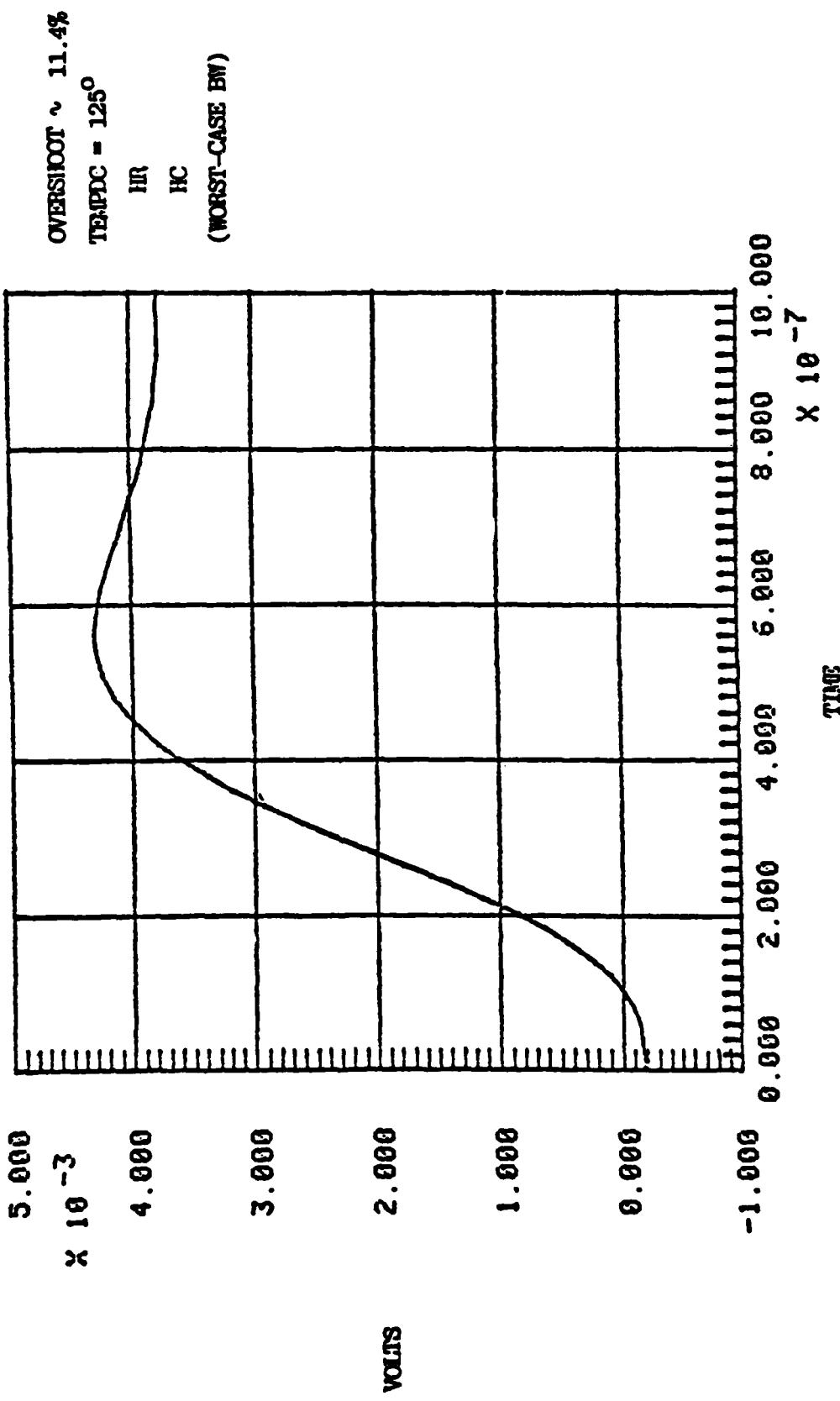


A₂ OPEN-LOOP PHASE

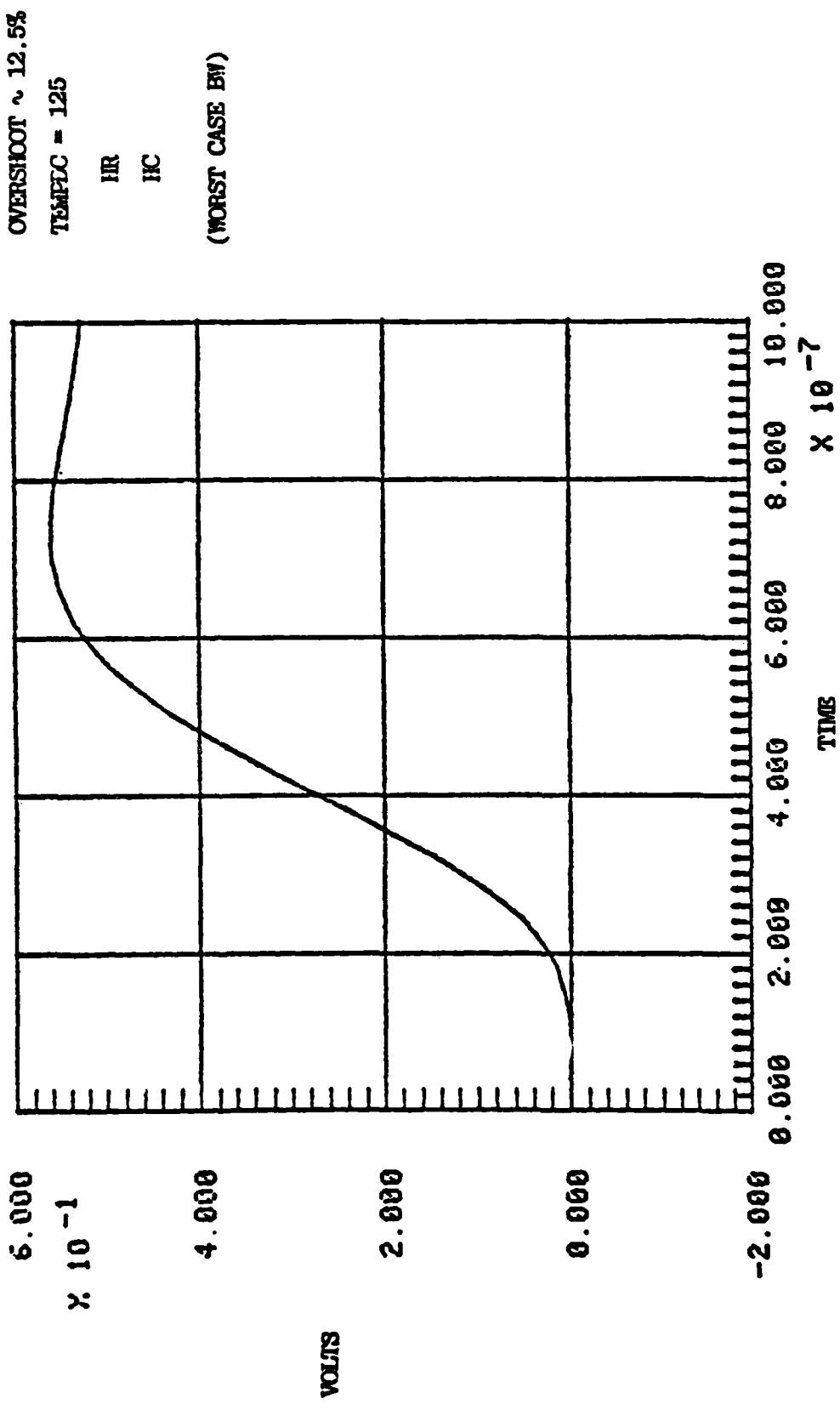


OVERALL STEP RESPONSE

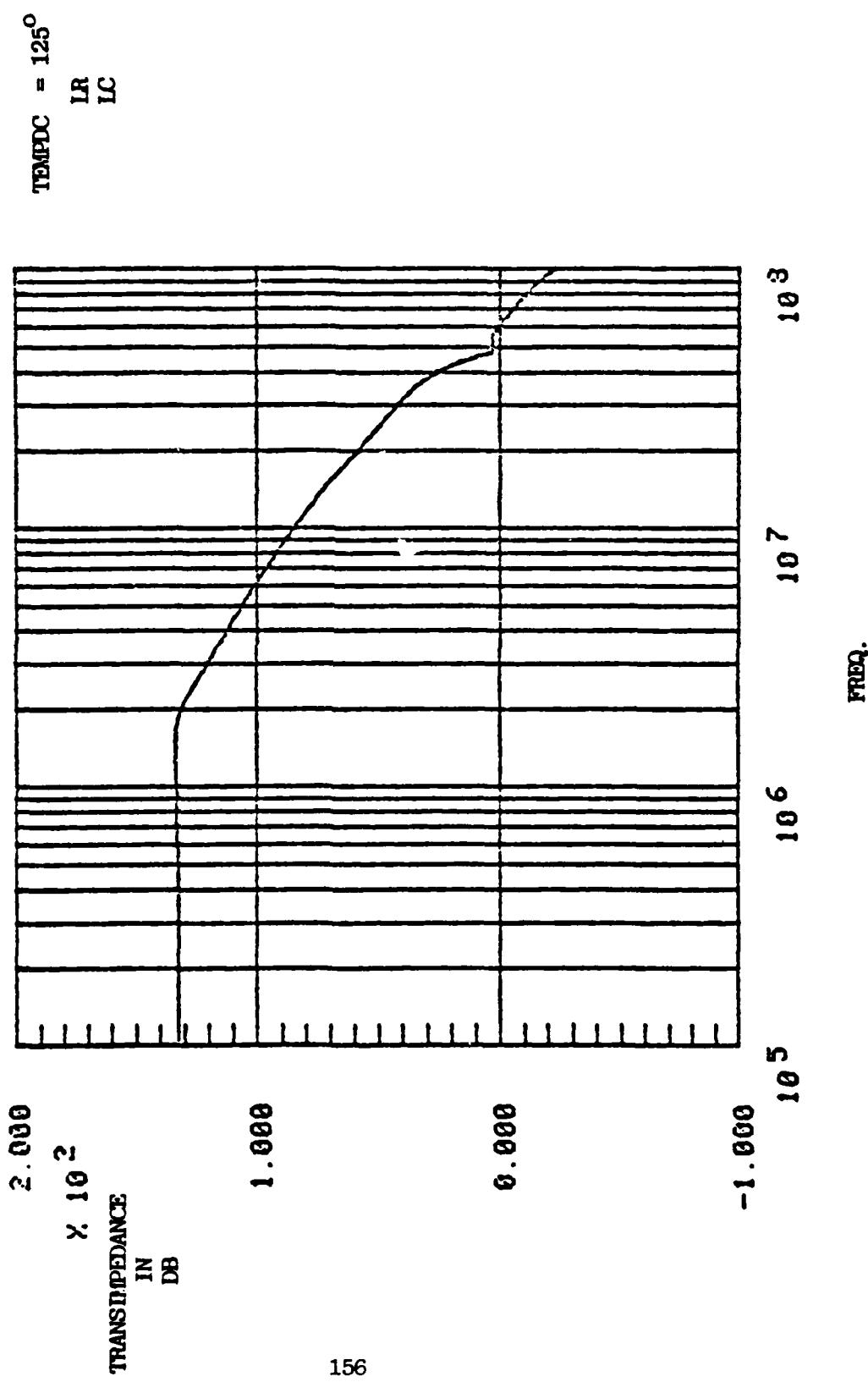
100 NA STEP



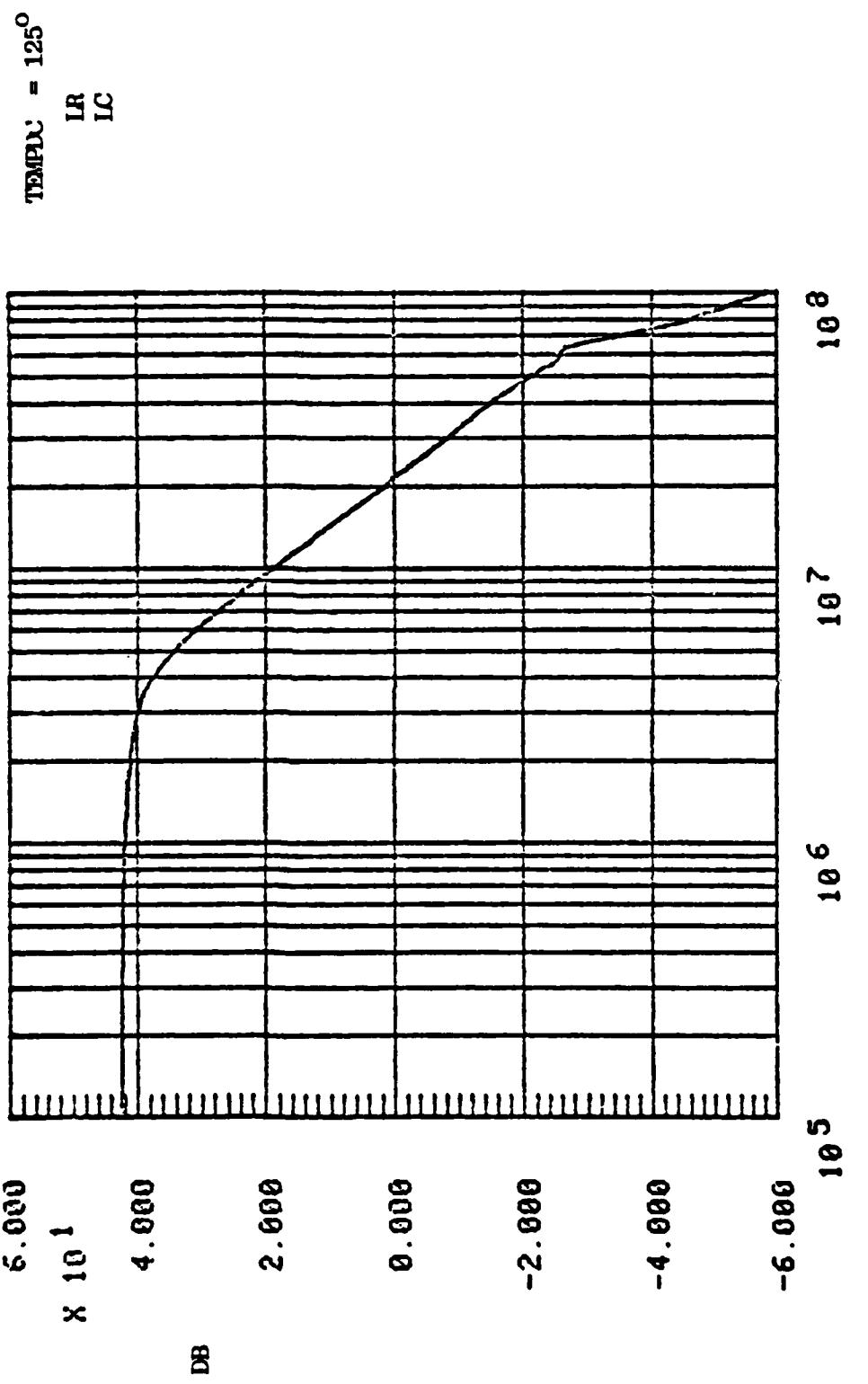
A₁ STEP RESPONSE
100 NA STEP



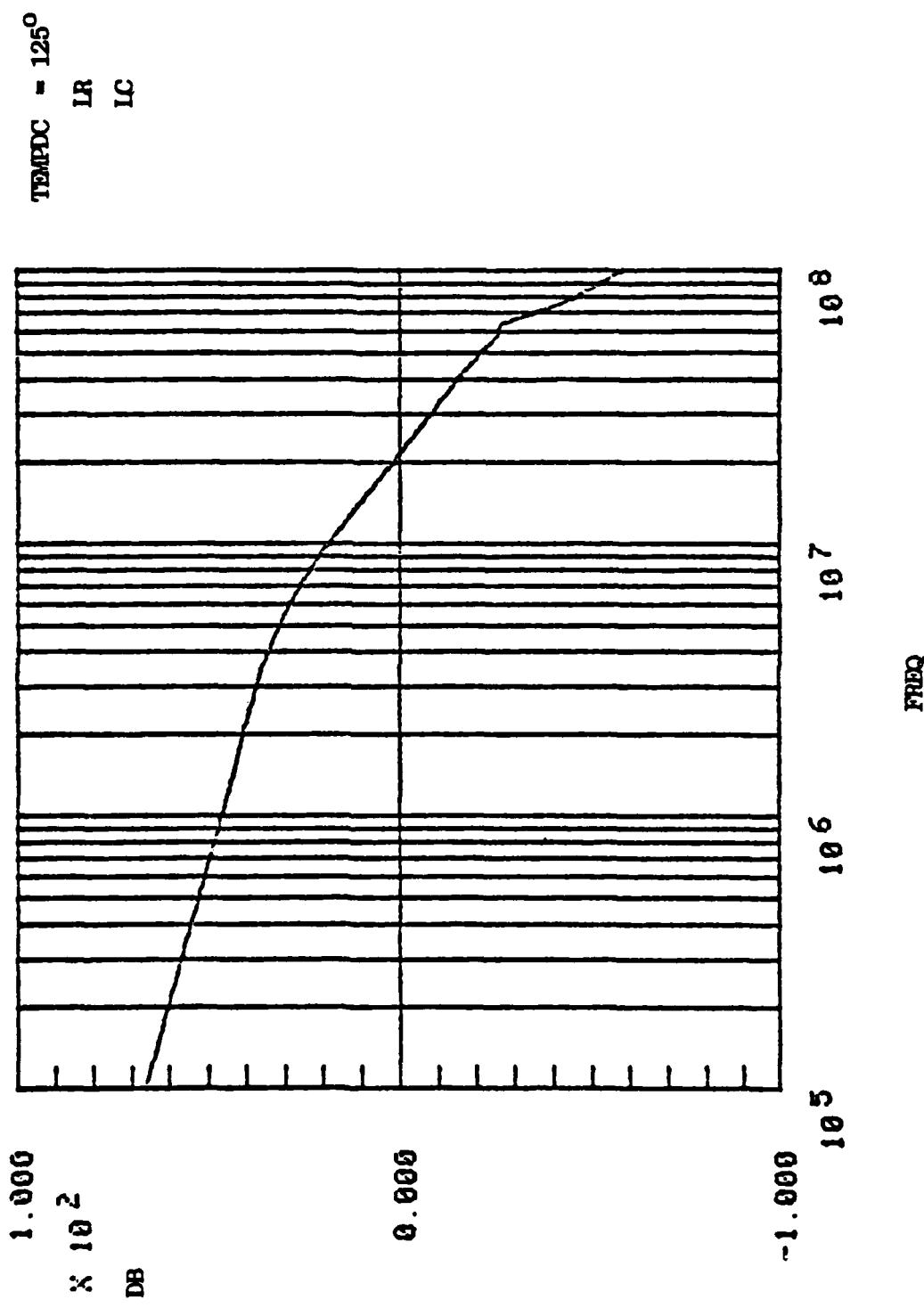
OVERALL GAIN



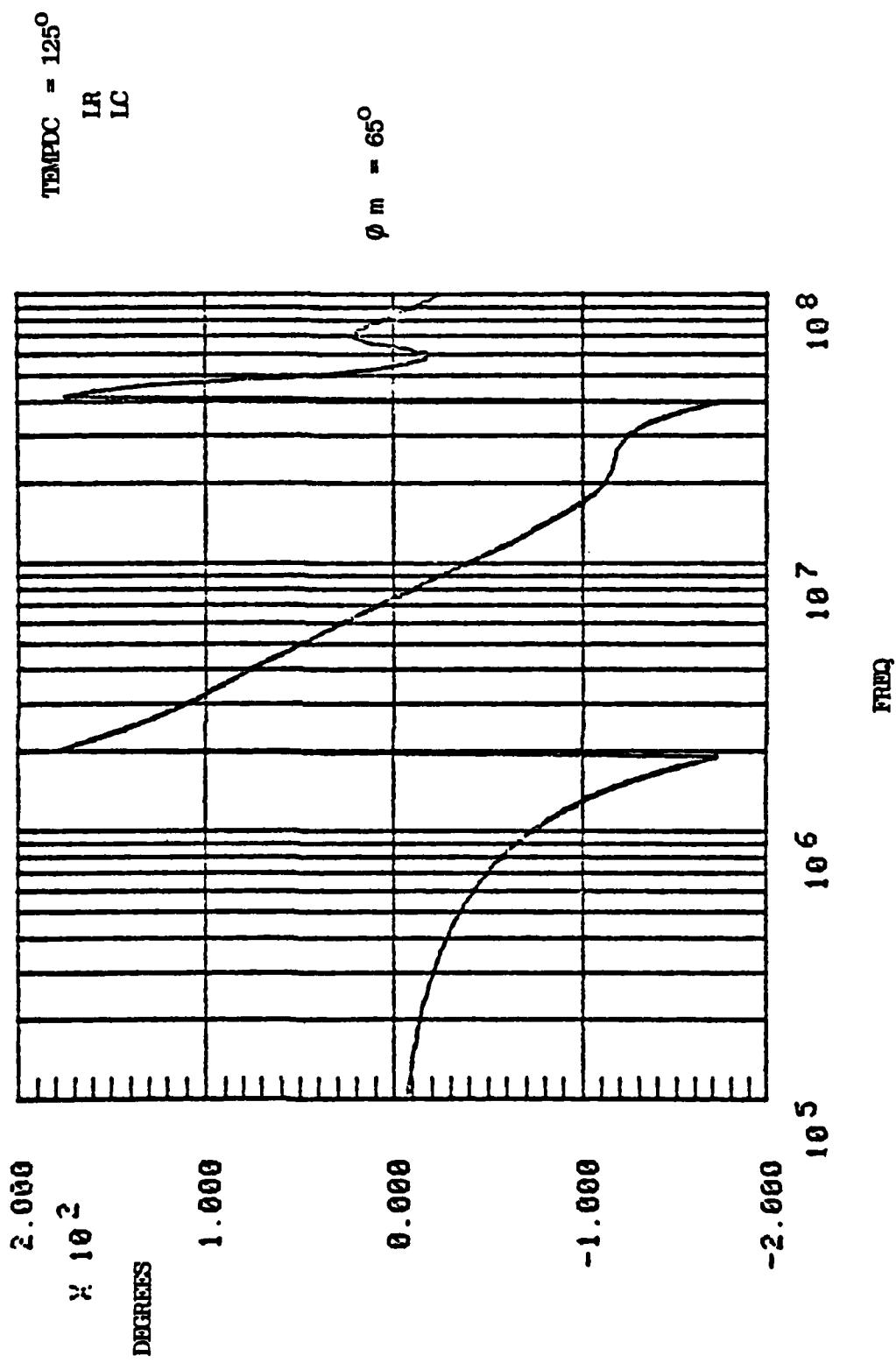
A_2 CLOSED-LOOP GAIN

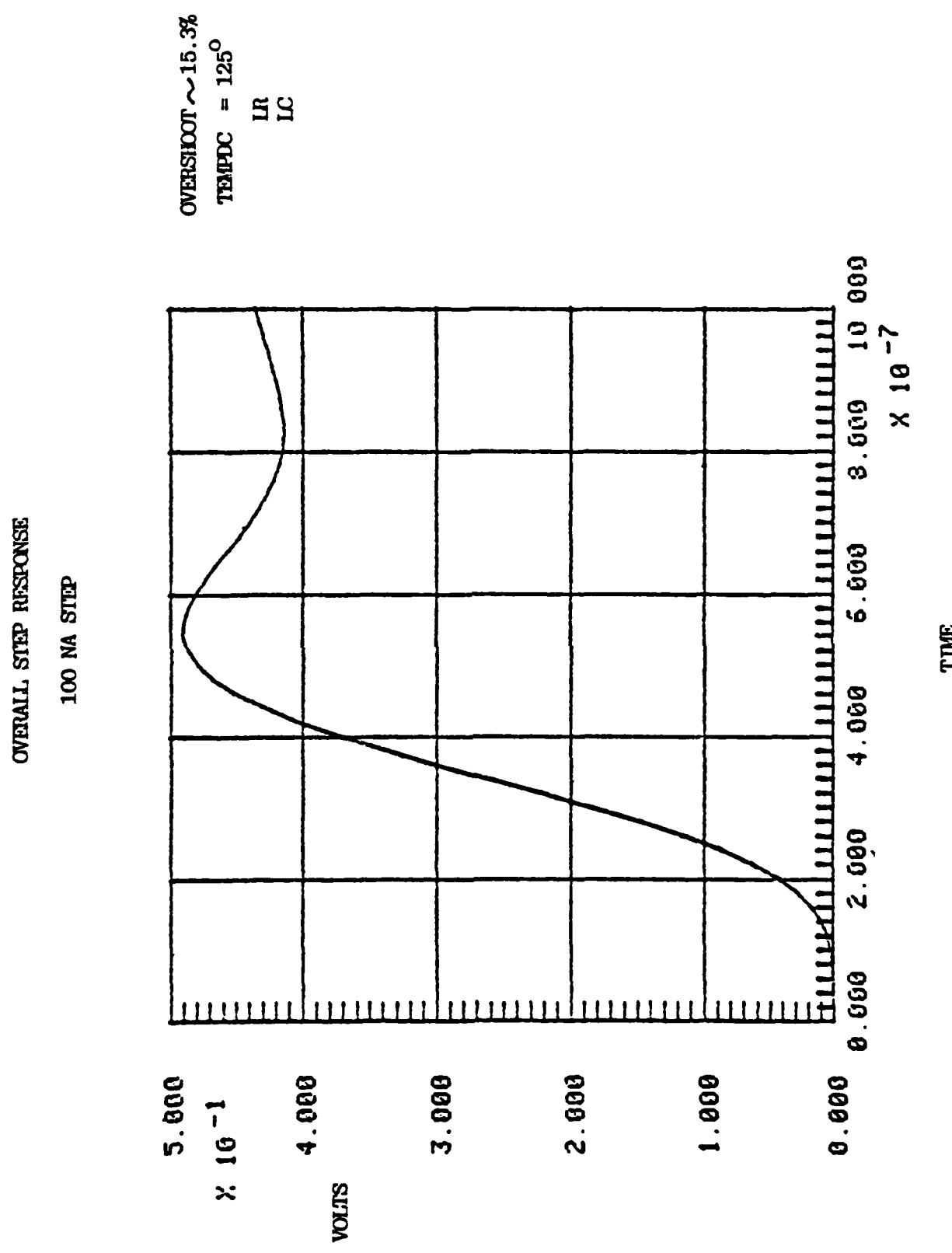


A_2 OPEN-LOOP GAIN

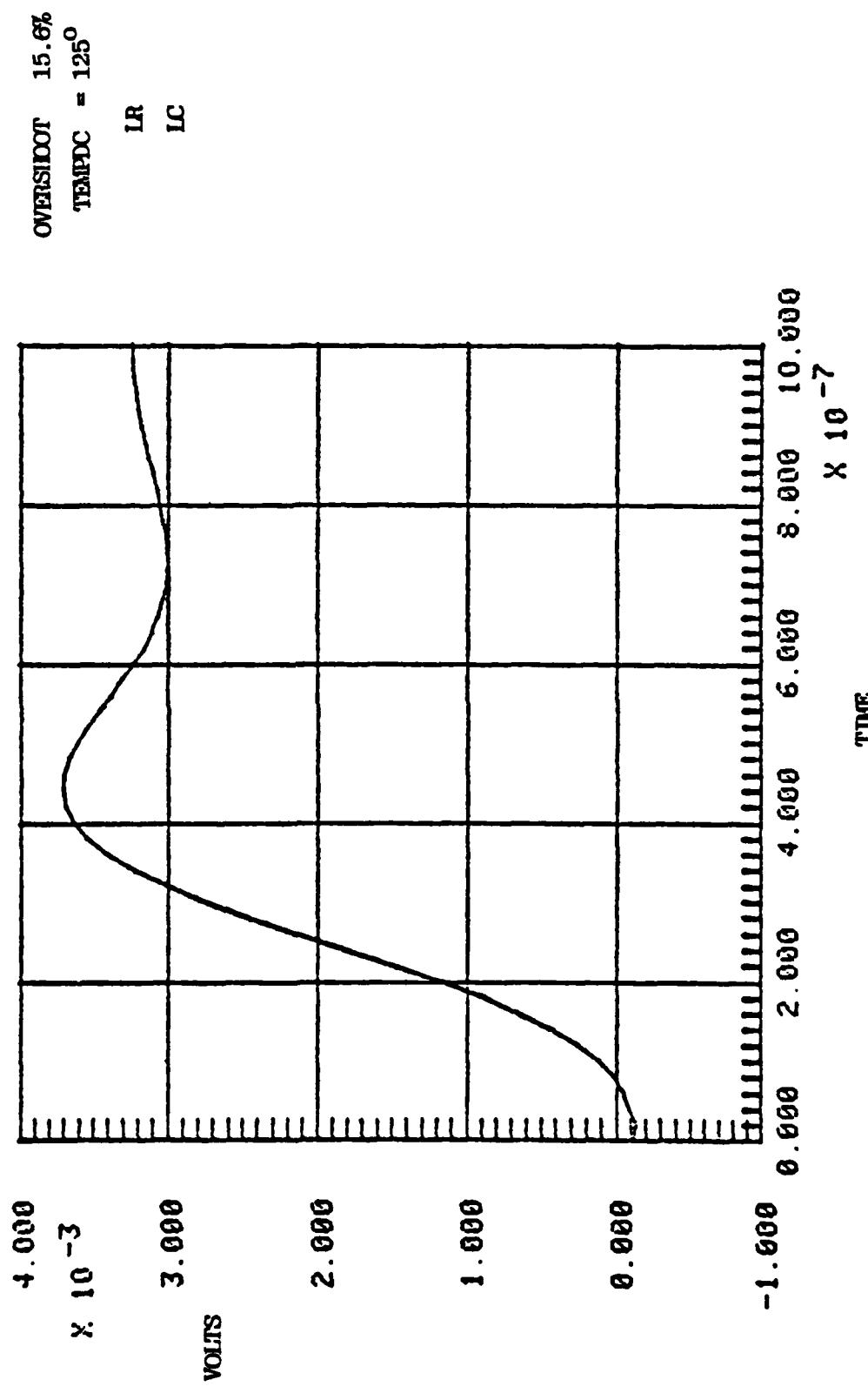


A_2 OPEN-LOOP PHASE

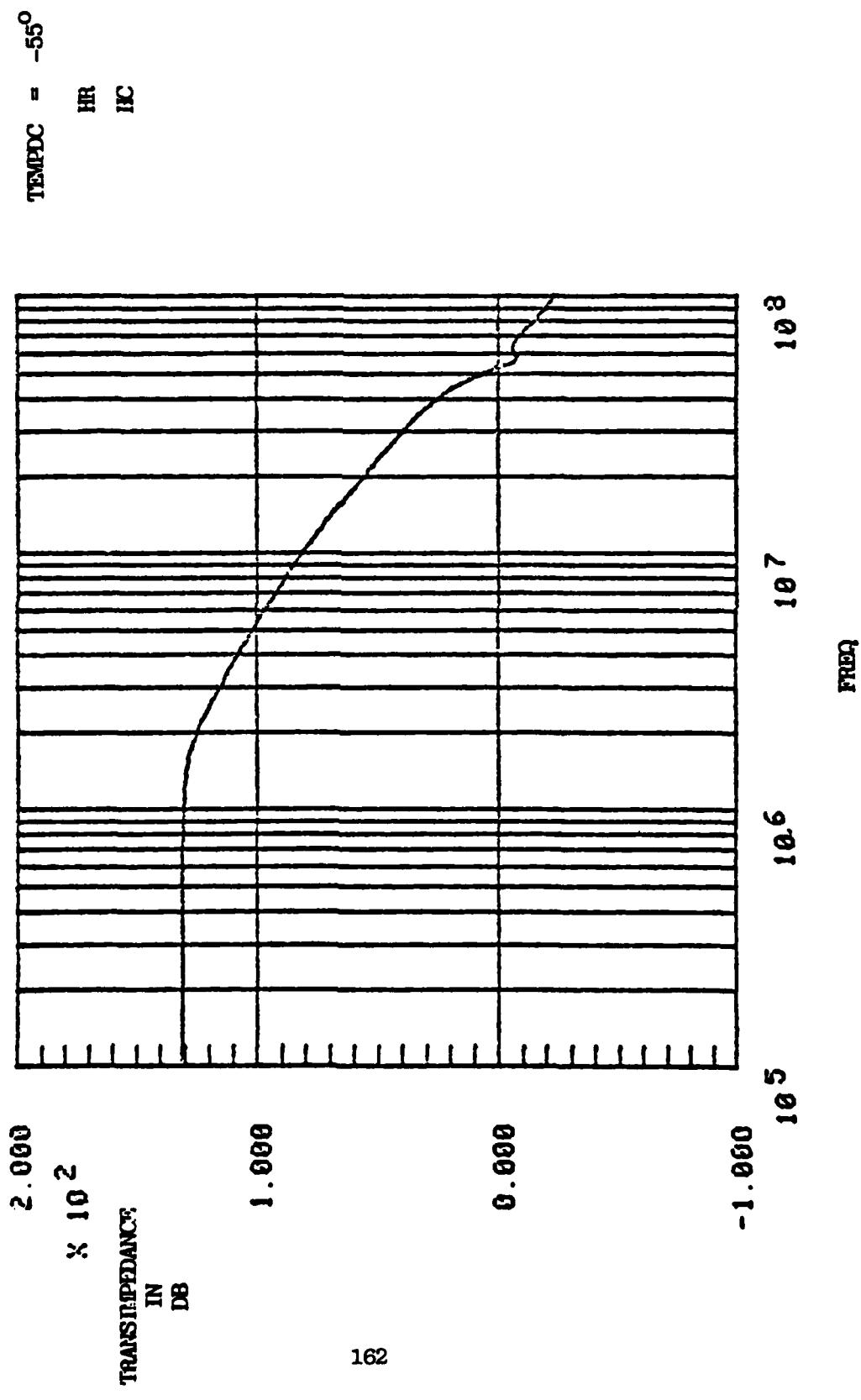




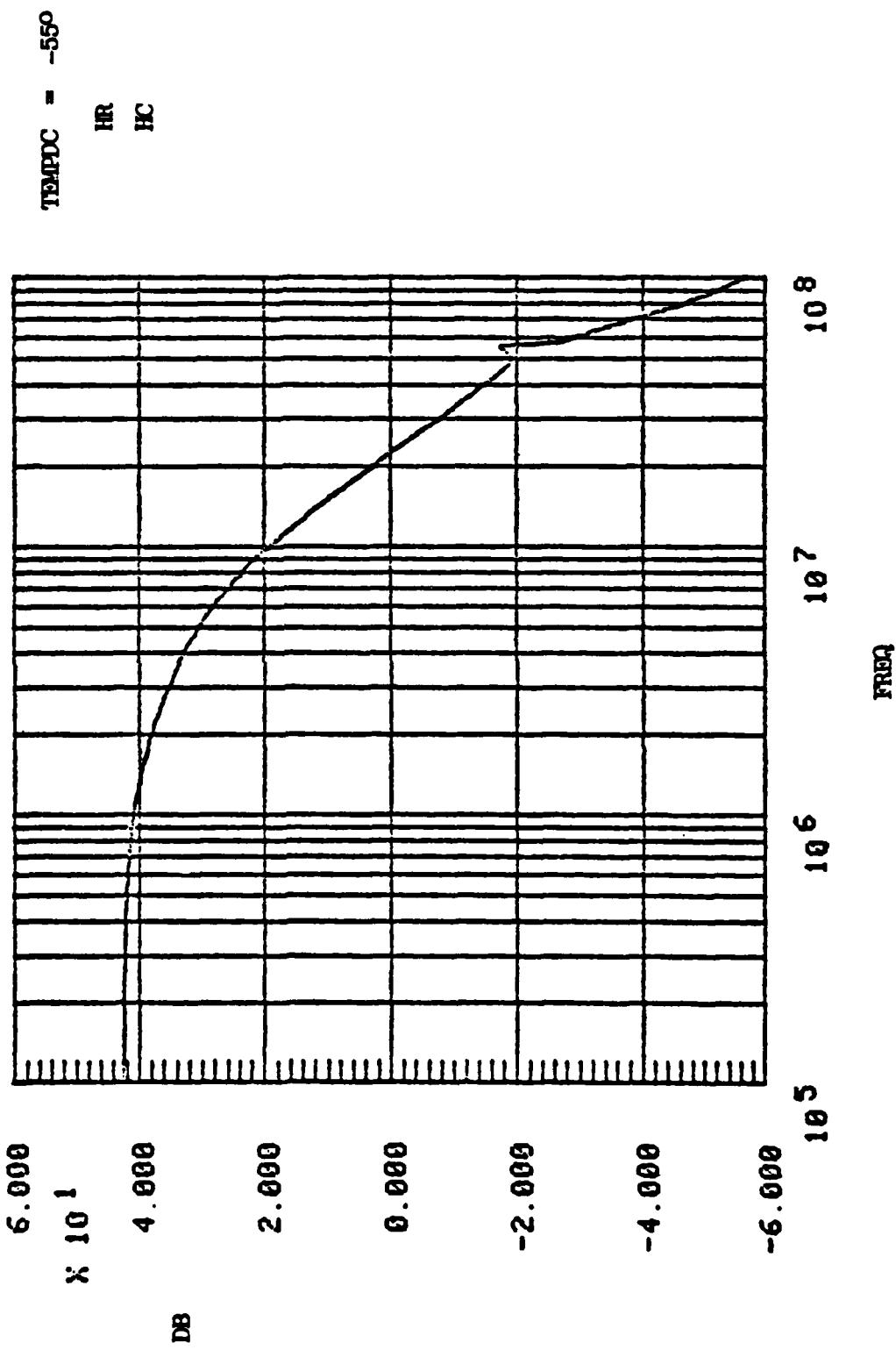
A_1 STEP RESPONSE



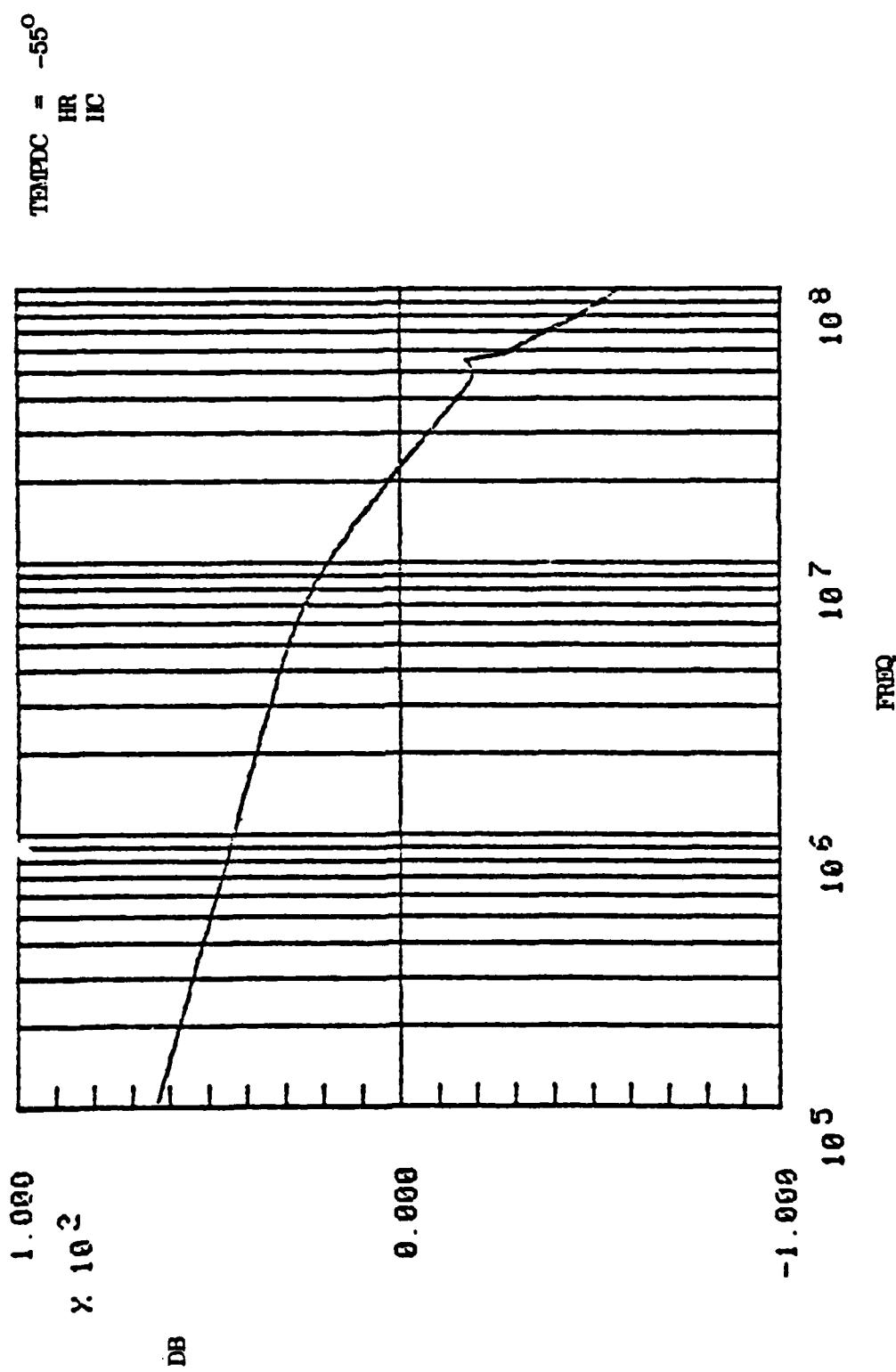
OVERALL GAIN



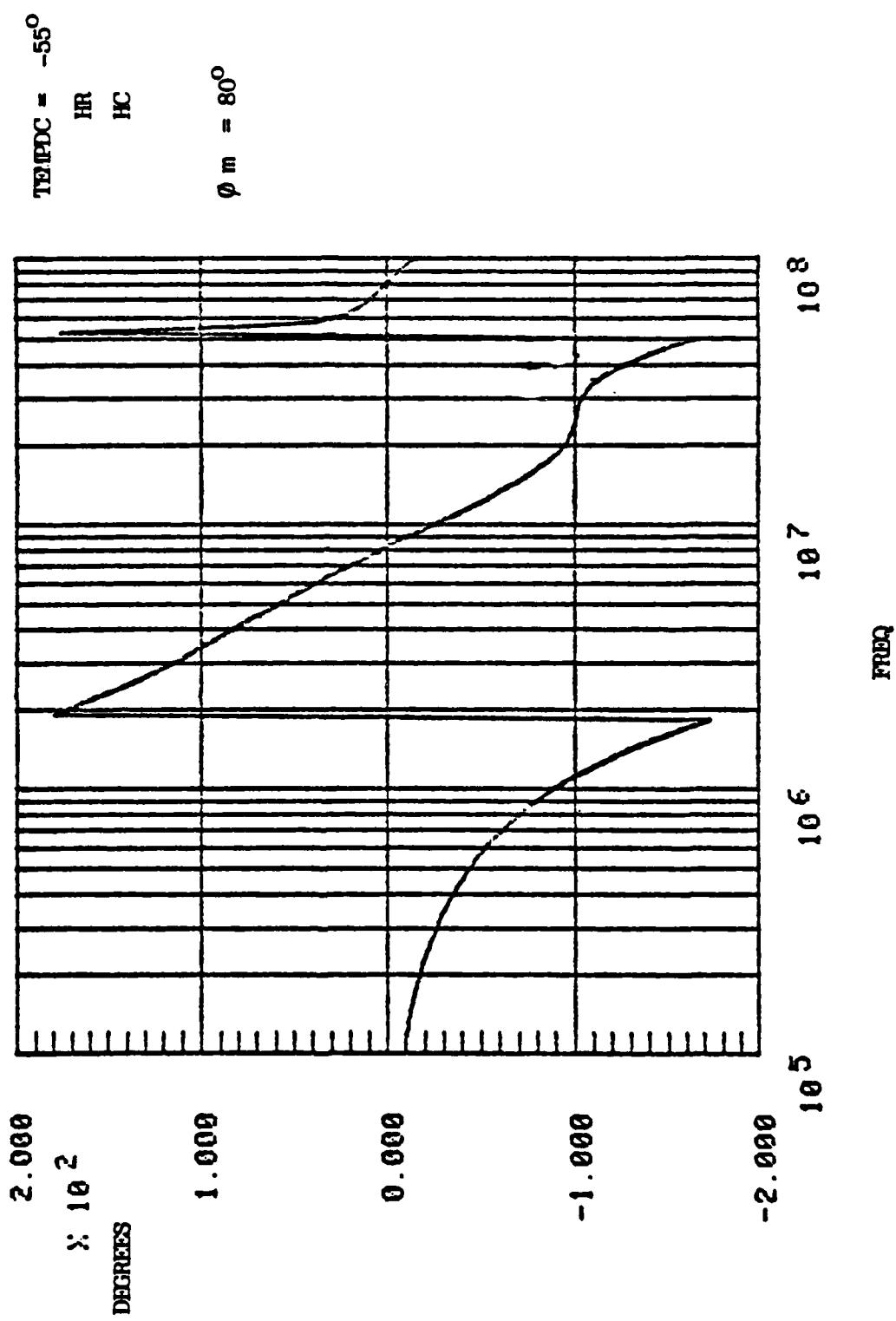
A₂ CLOSED-LOOP GAIN



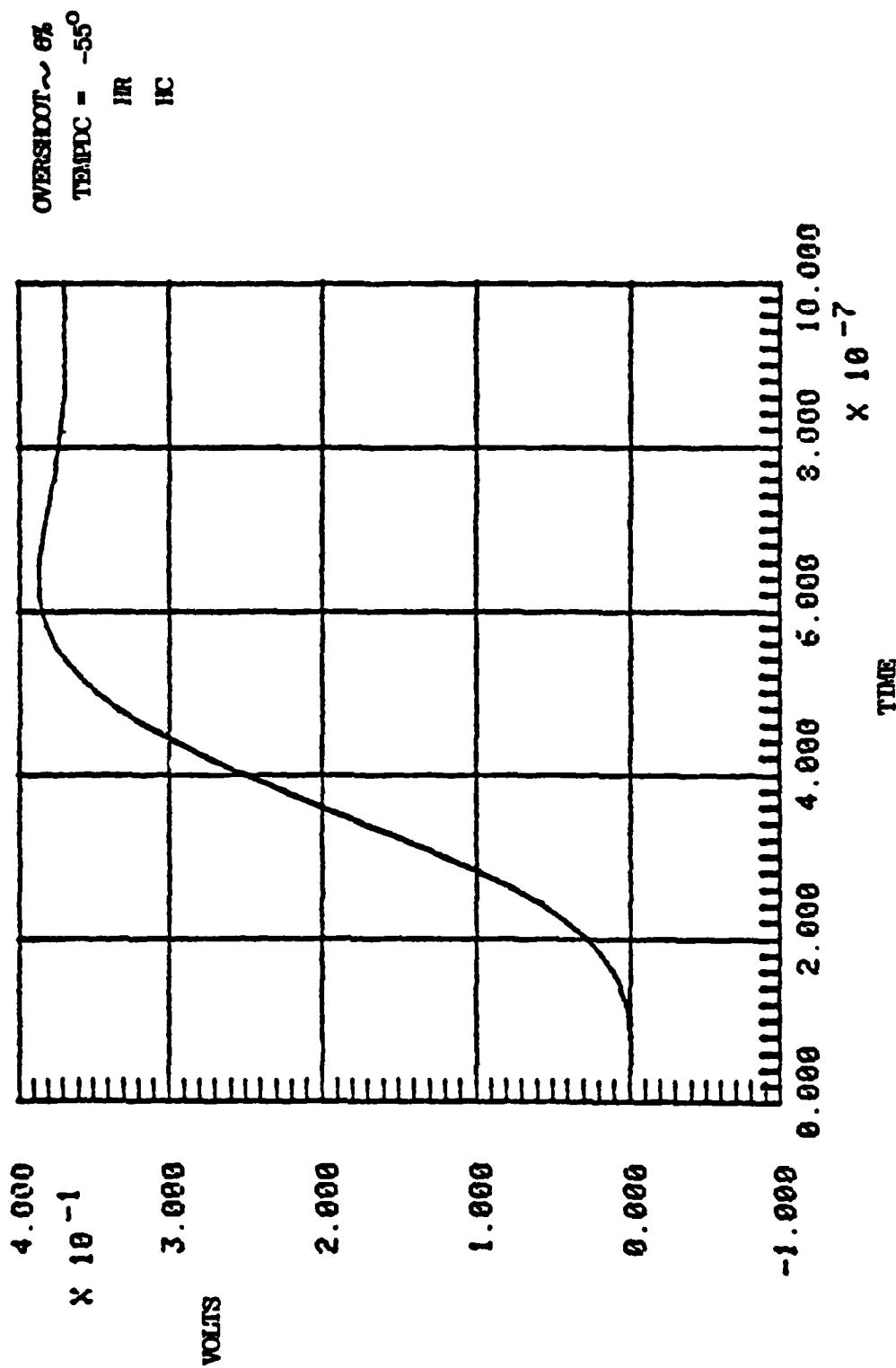
A_2 OPEN-LOOP GAIN



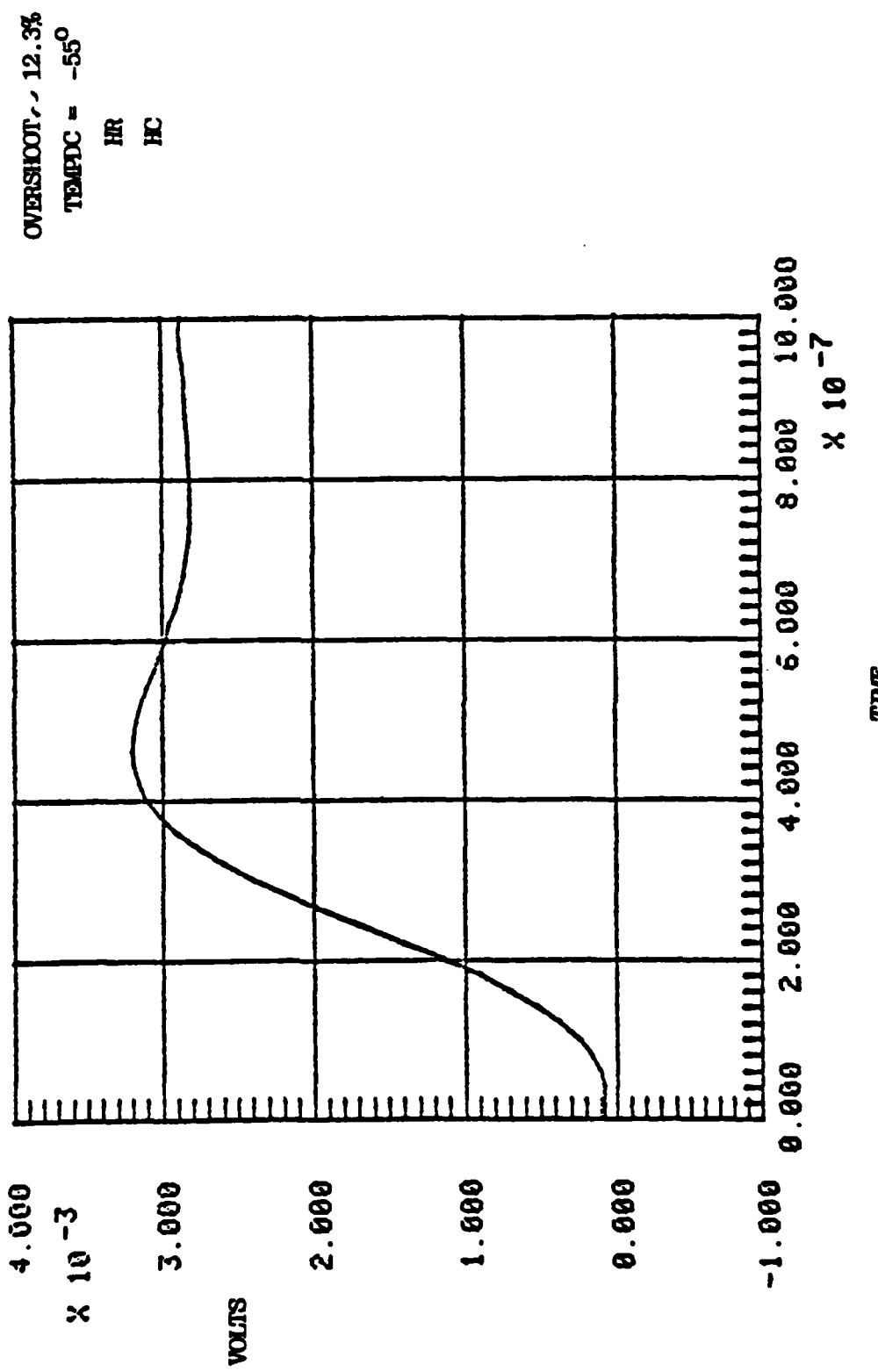
A_2 OPEN-LOOP PHASE



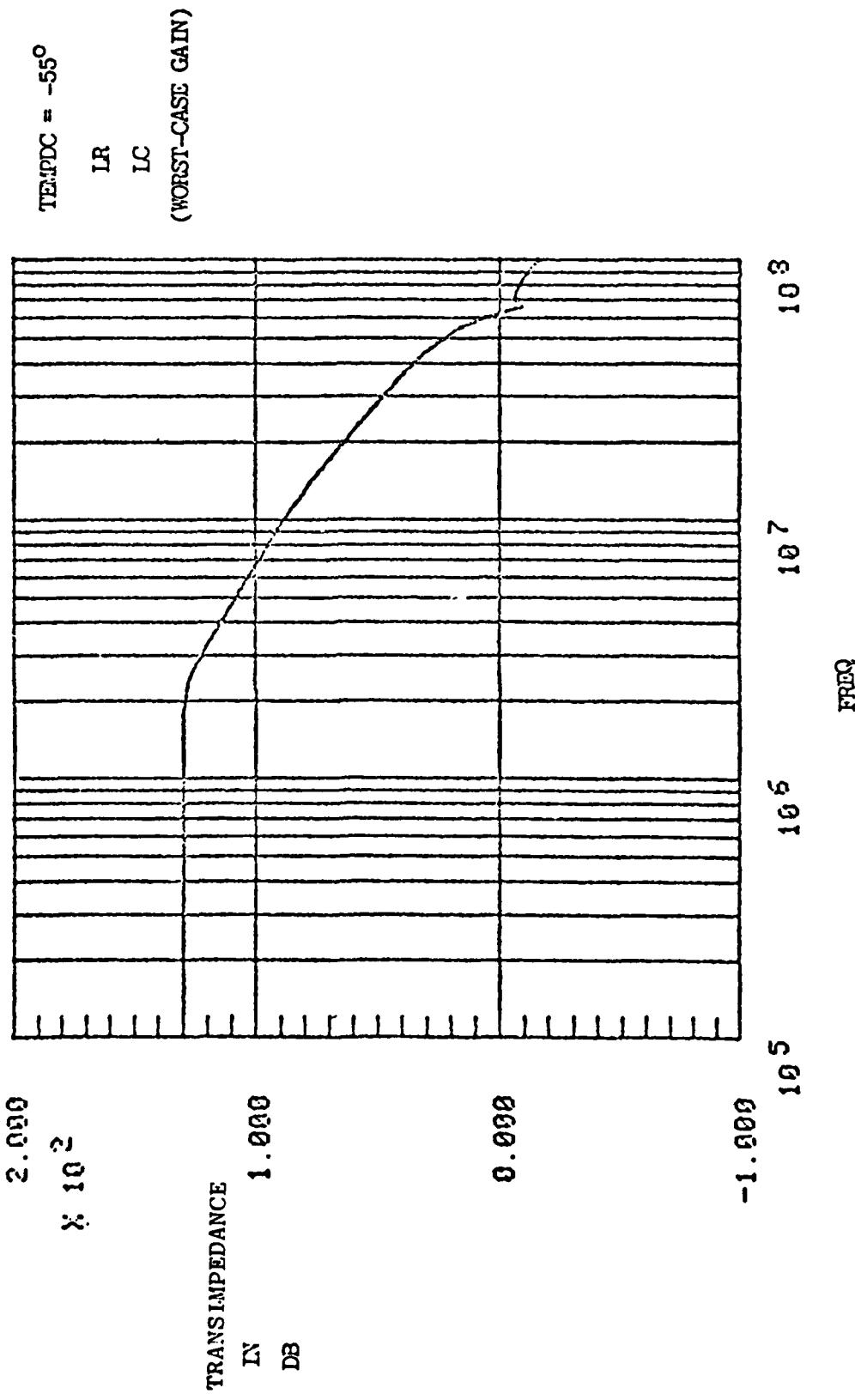
OVERALL STEP RESPONSE
100 MA STEP



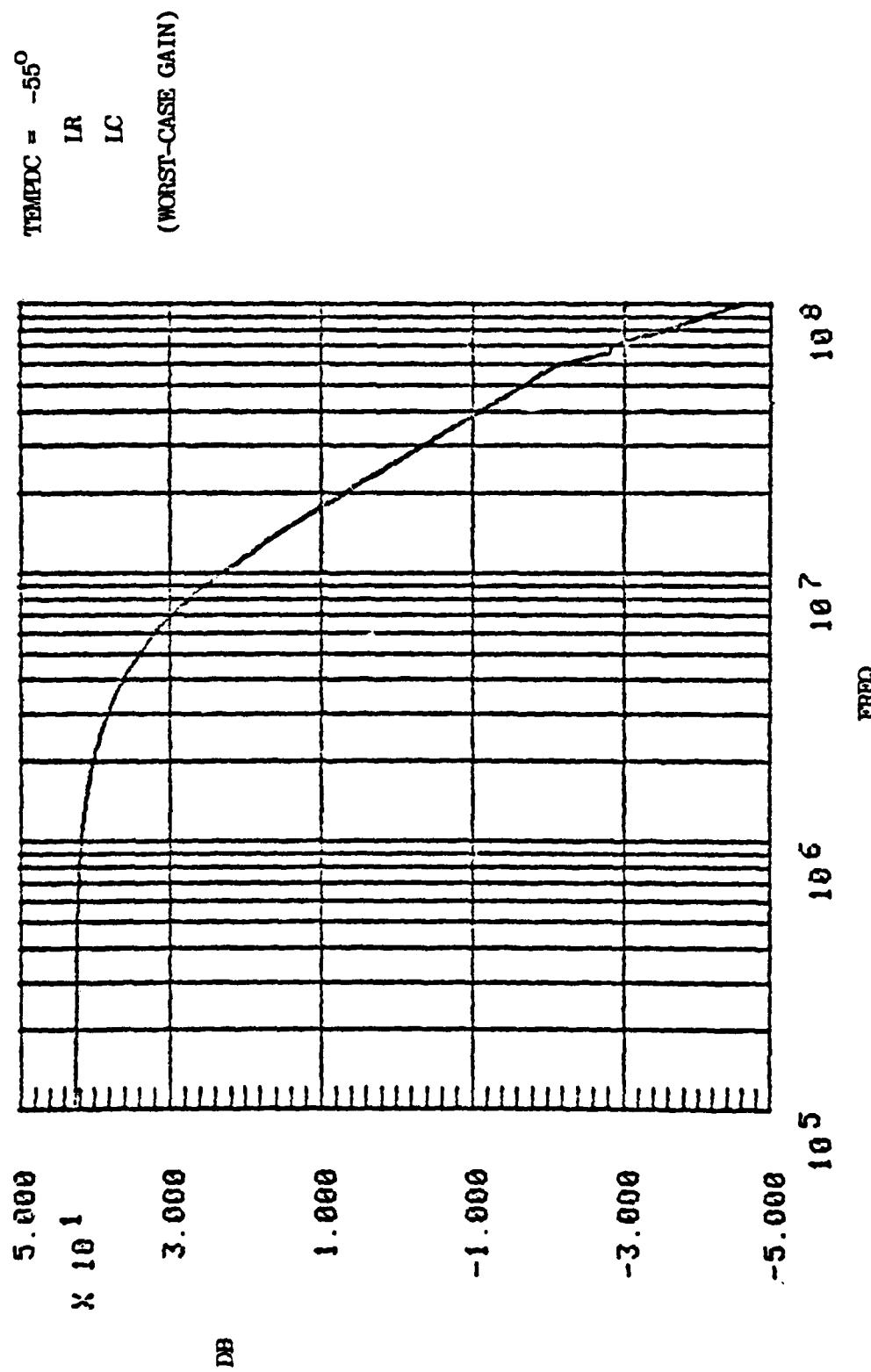
A_1 STEP RESPONSE
100 NA STEP



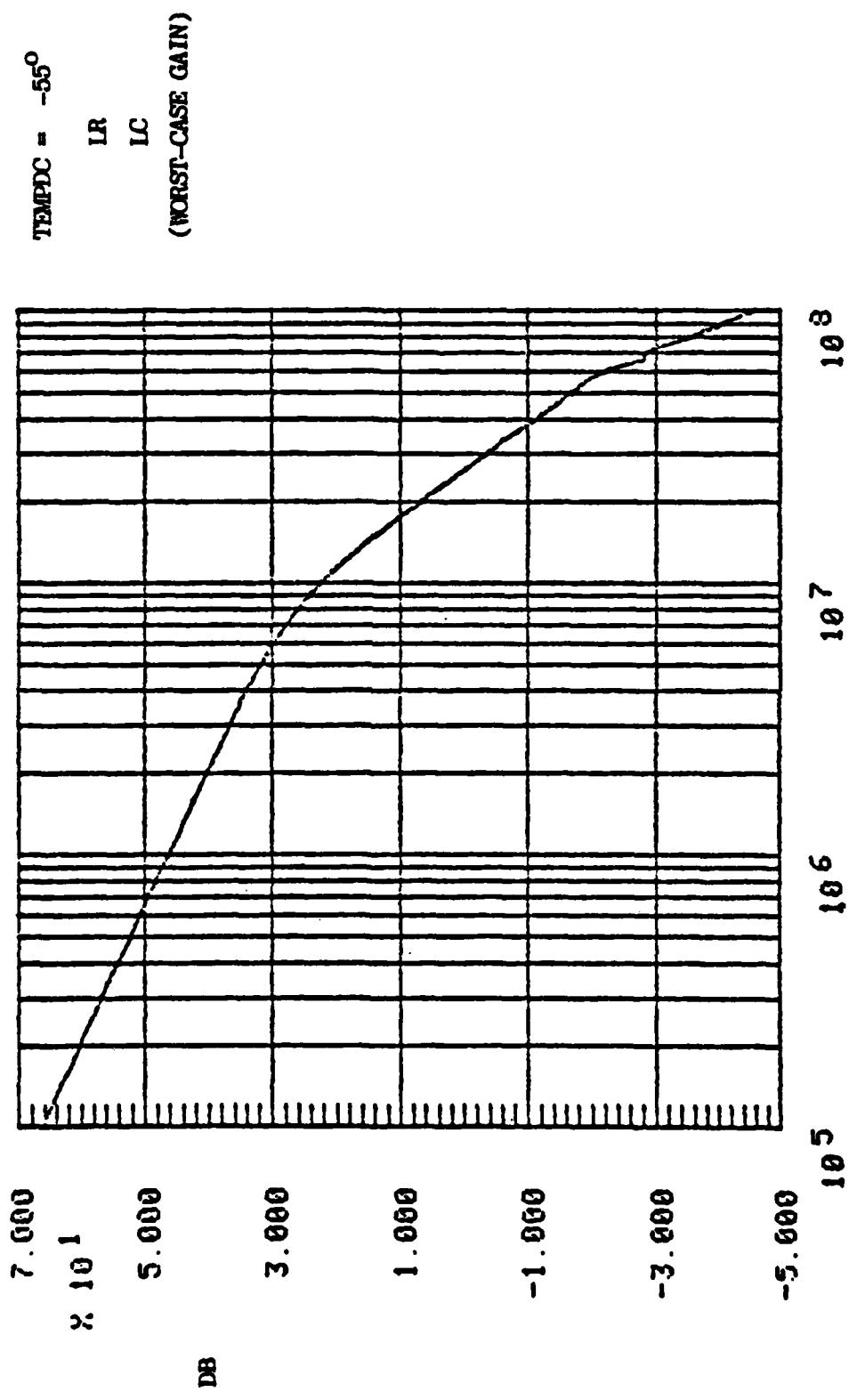
OVERALL GAIN



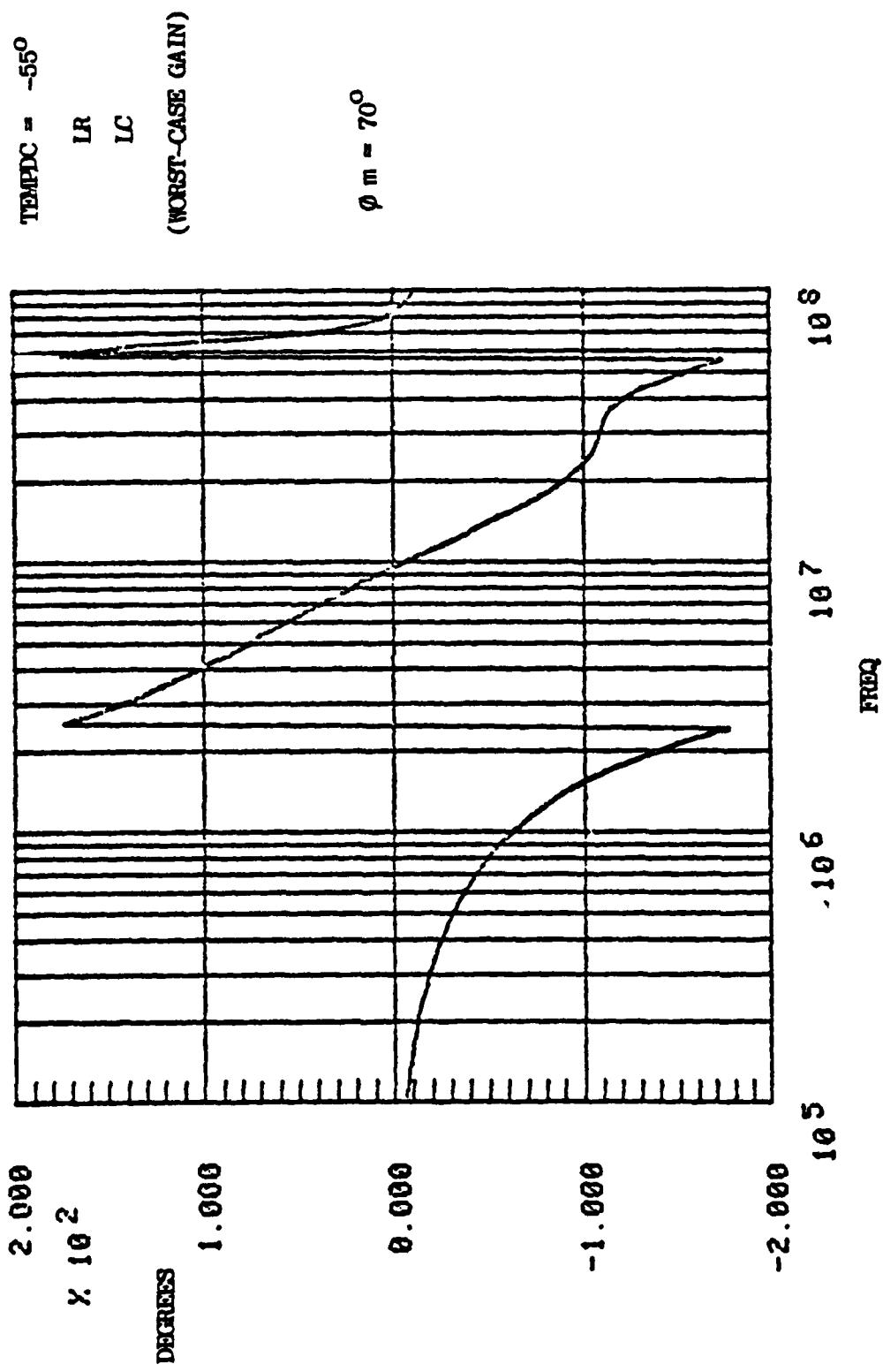
A_2 CLOSE-LOOP GAIN



A_2 OPEN-LOOP GAIN

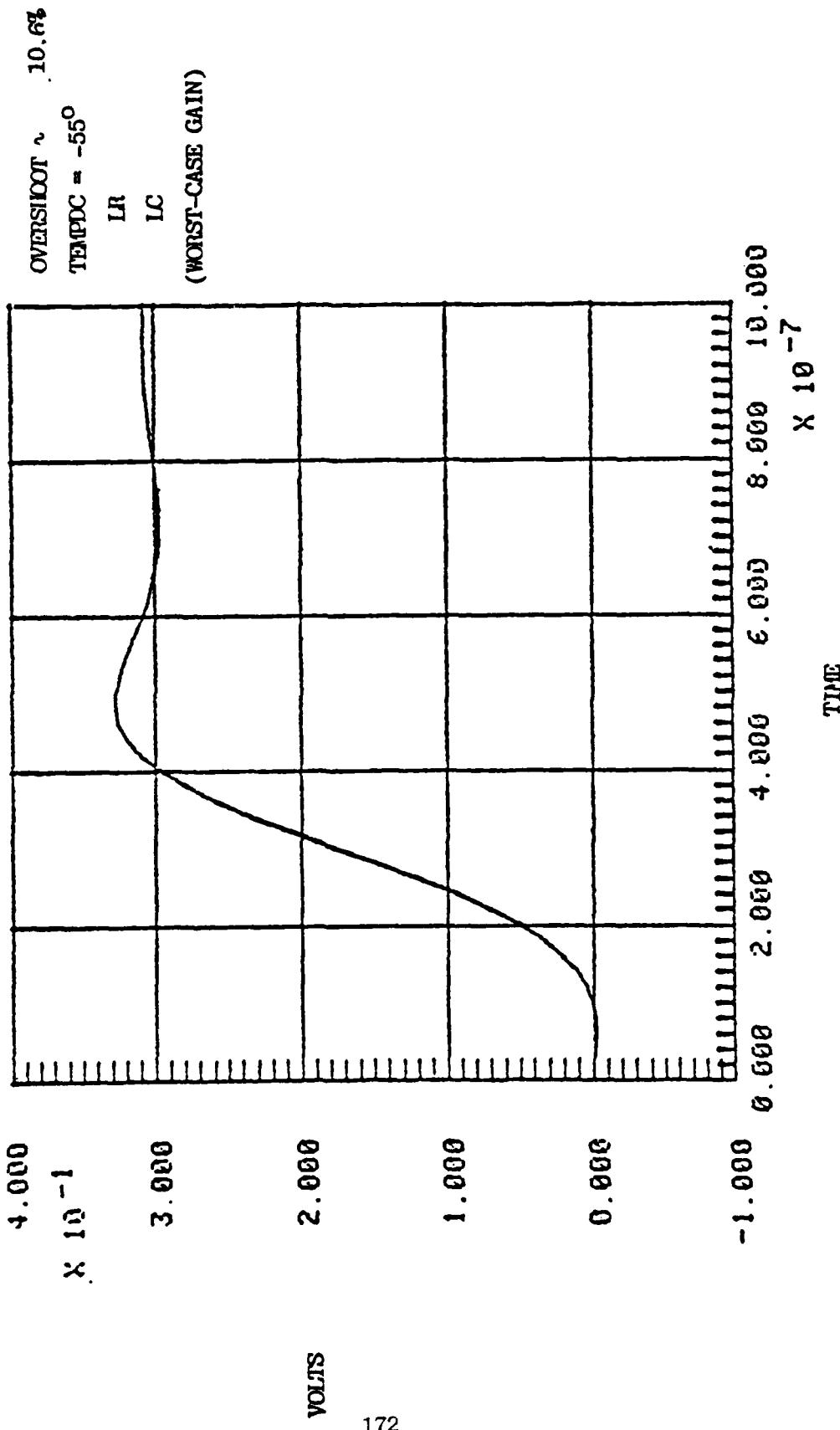


A₂ OPEN-LOOP PHASE



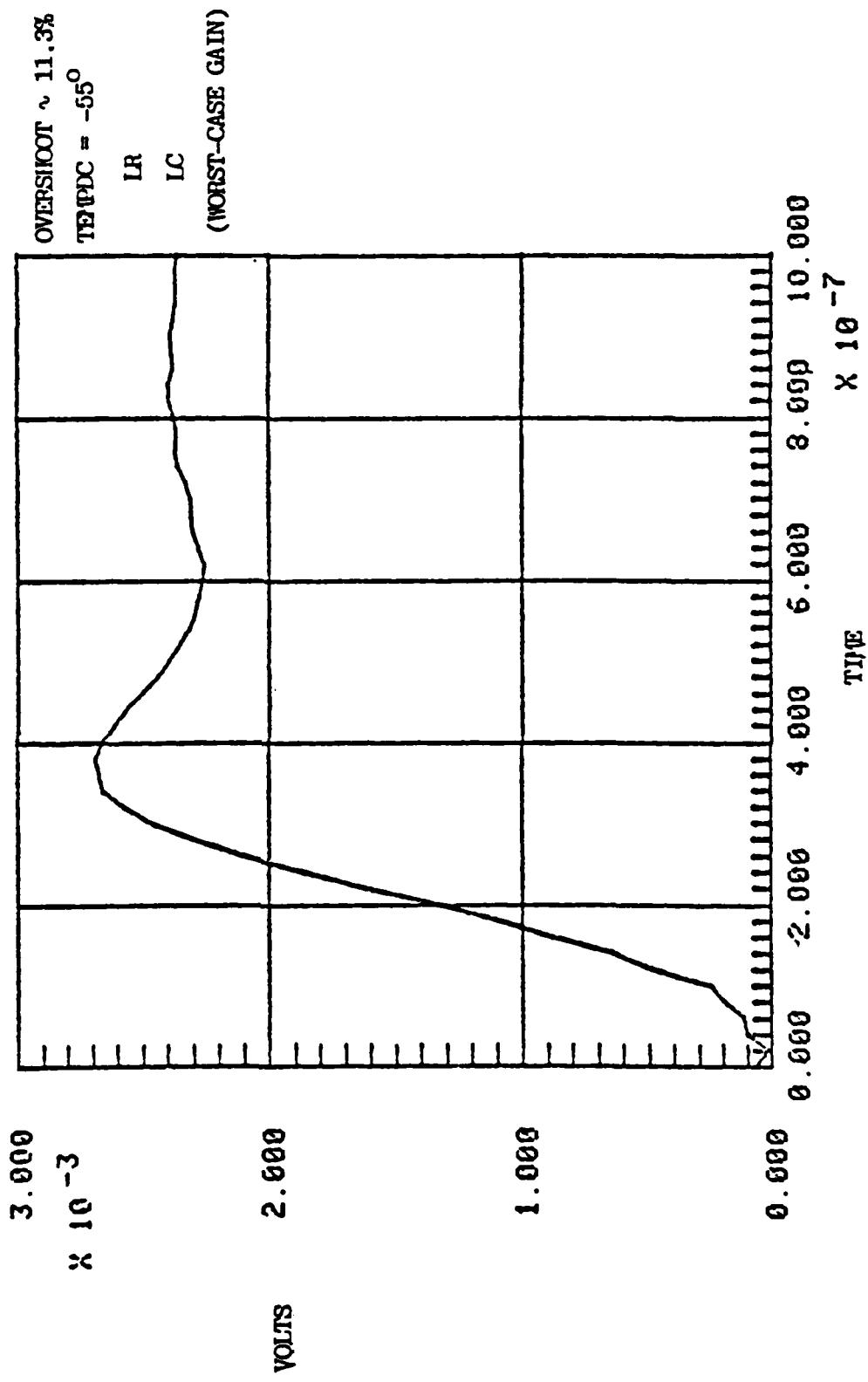
OVERALL STEP RESPONSE

100 NA STEP



A_1 STEP RESPONSE

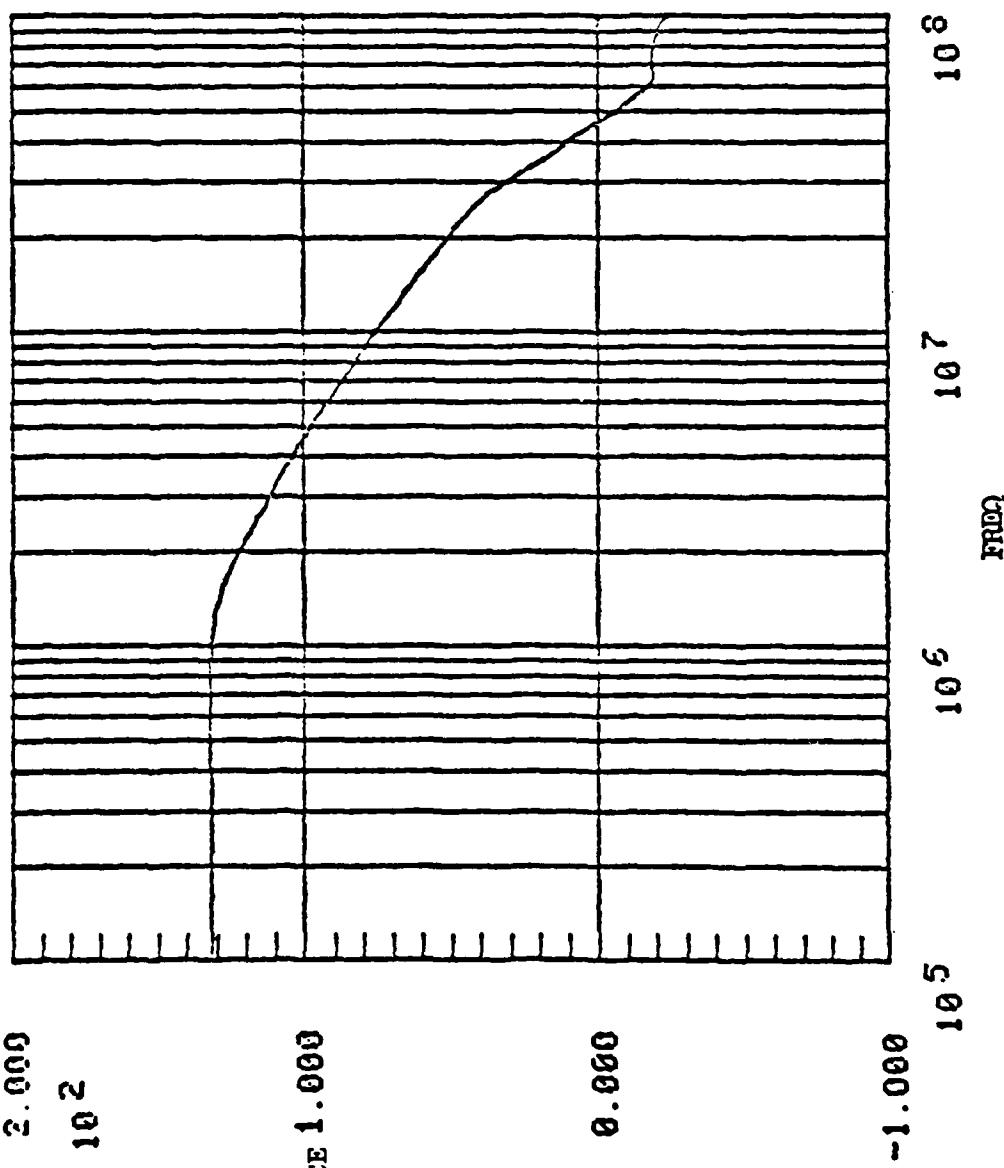
100 NA STEP



OVERALL GAIN

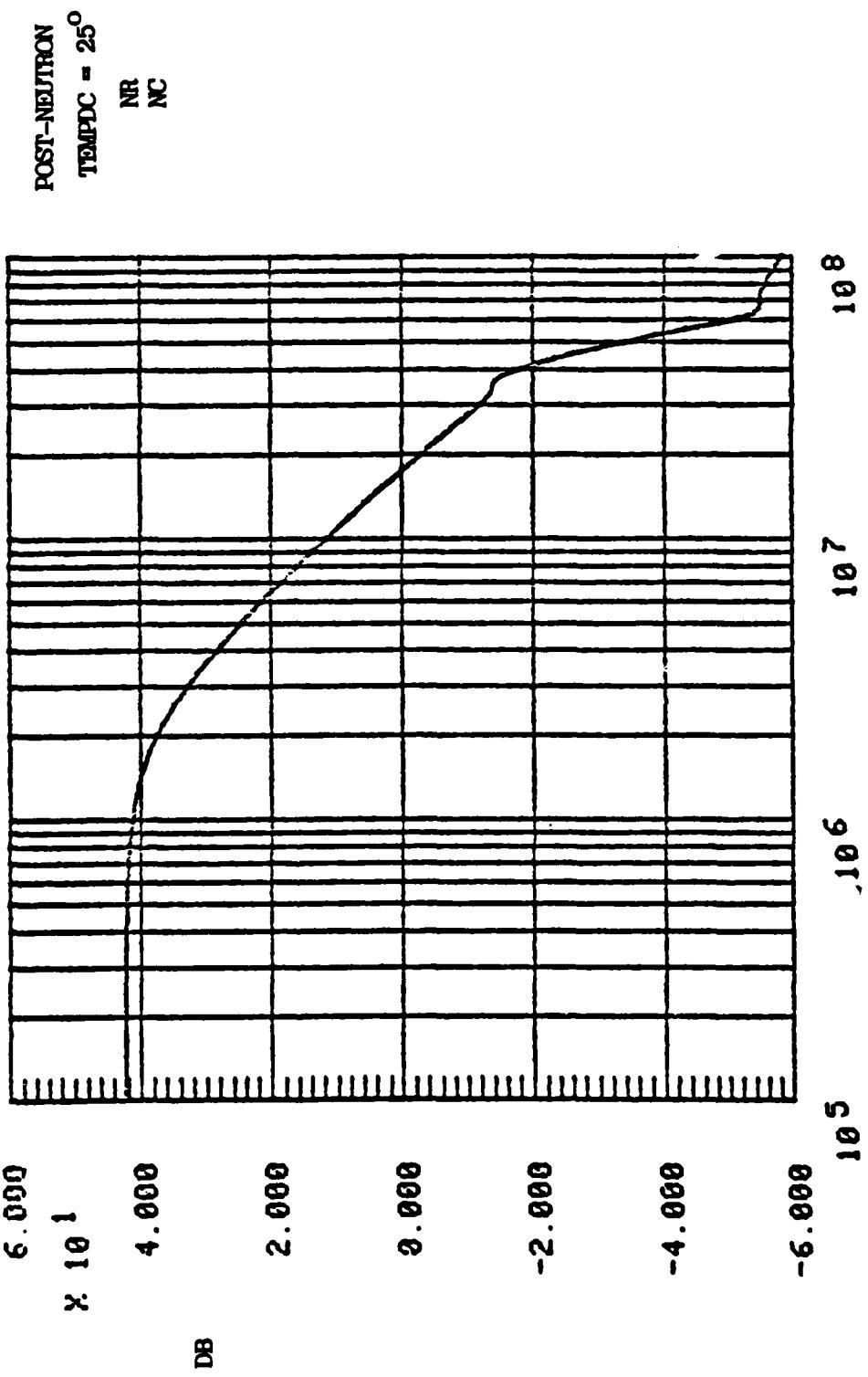
१०२

TRANSIMPEDANCE 1.000 IN DB

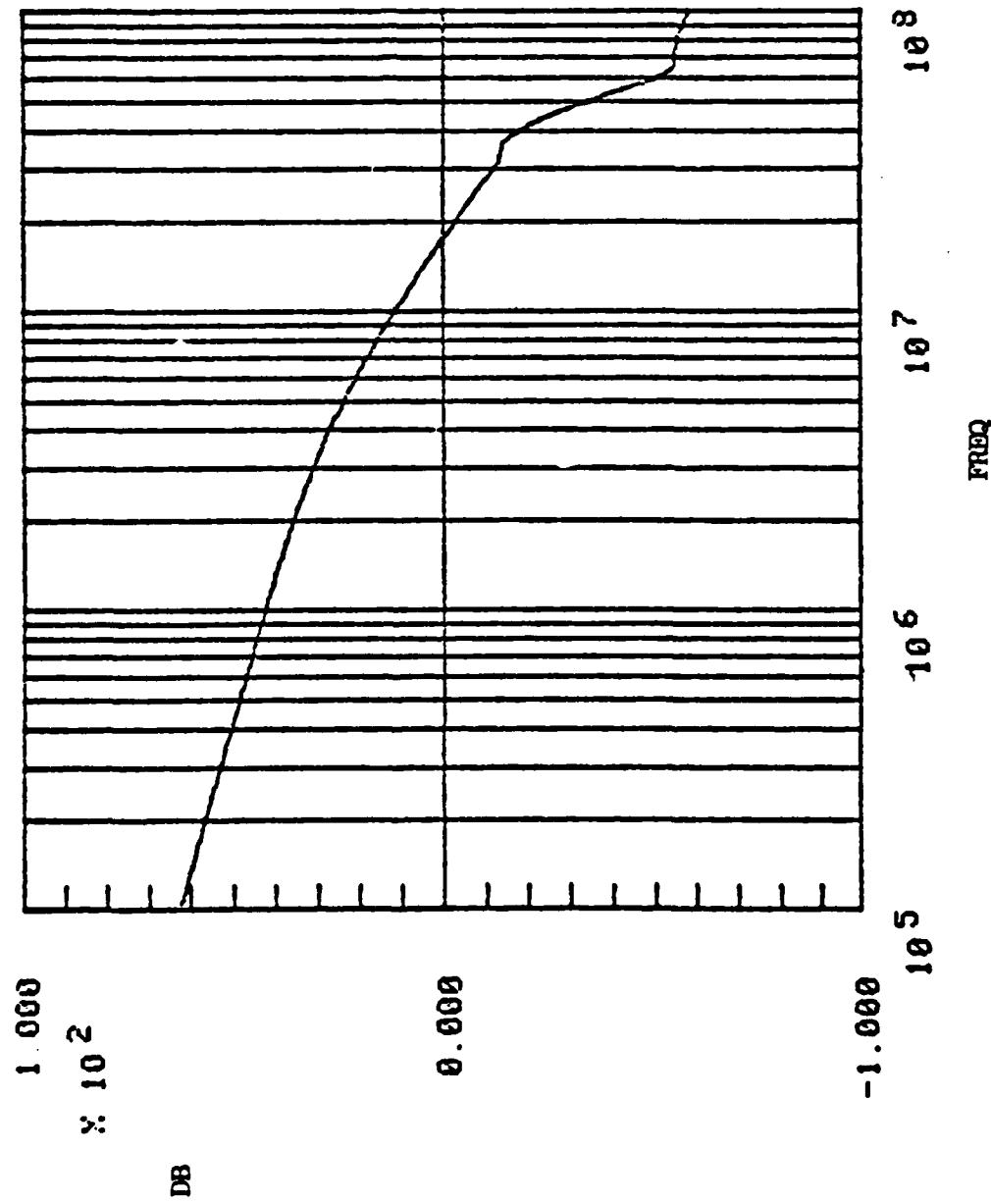


174

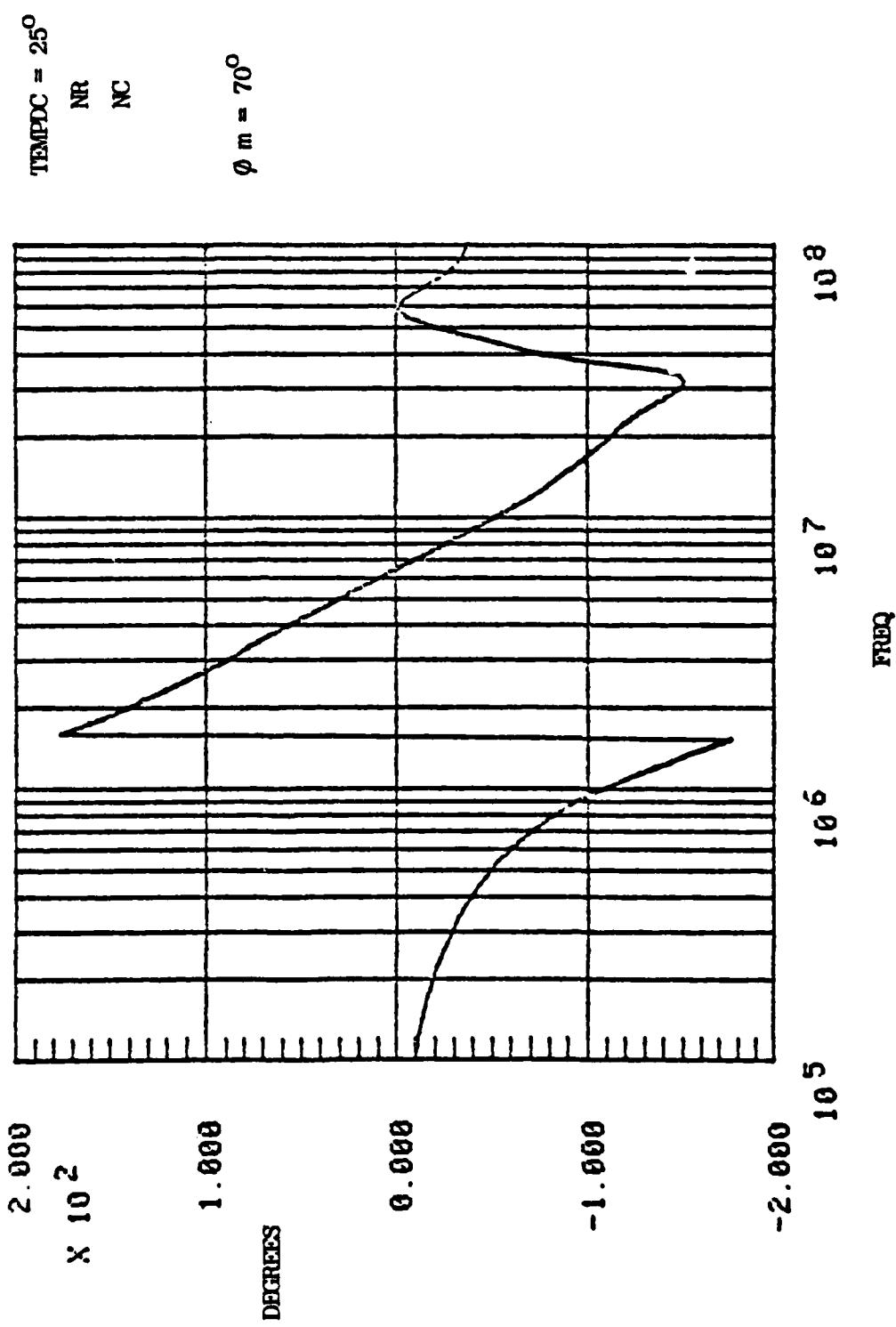
A_2 CLOSERD-LOOP GAIN



A_2 OPEN-LOOP GAIN

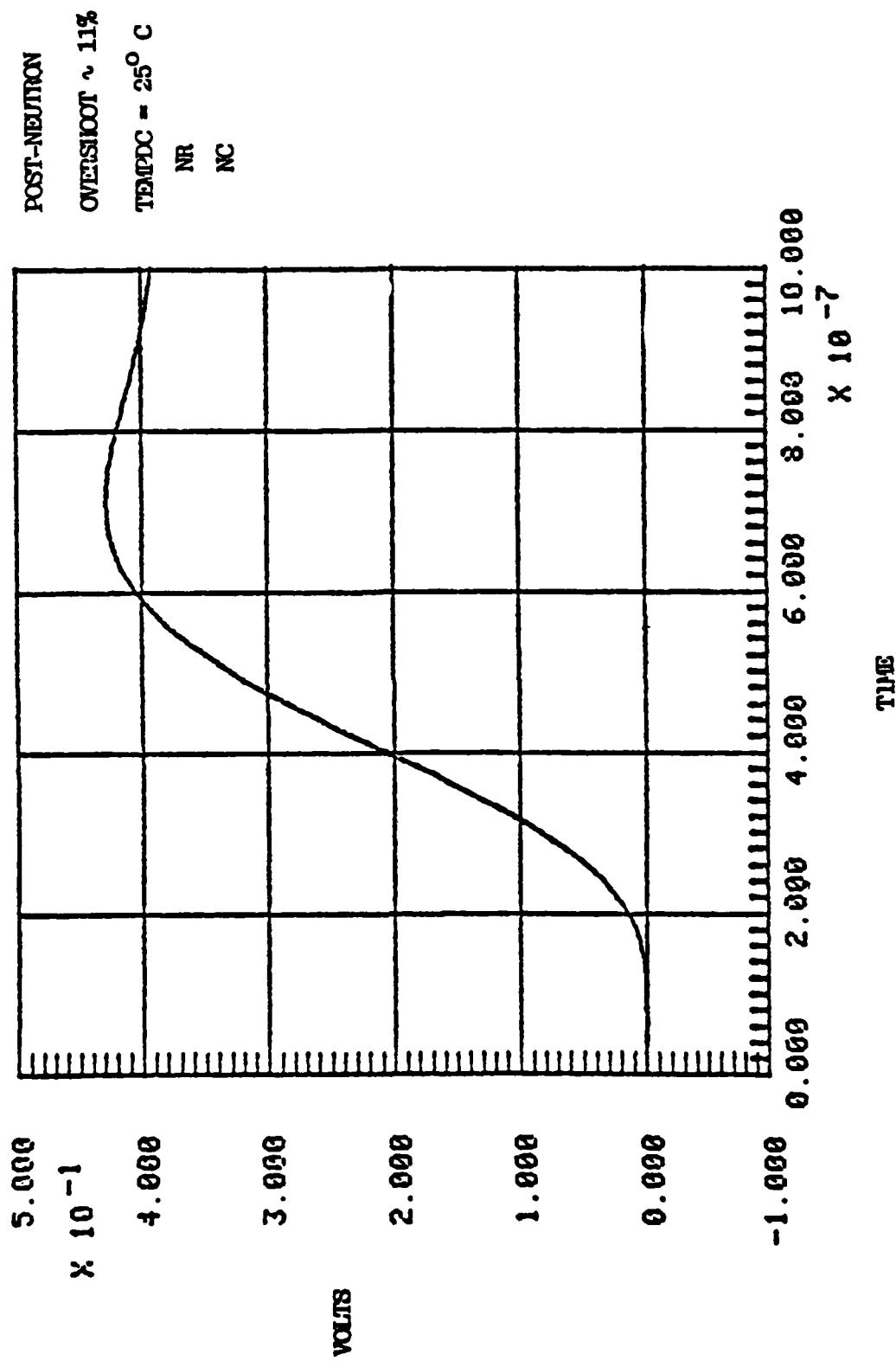


A_2 OPEN-LOOP PHASE



OVERALL STEP RESPONSE

100 MA STEP



A₁ STEP RESPONSE

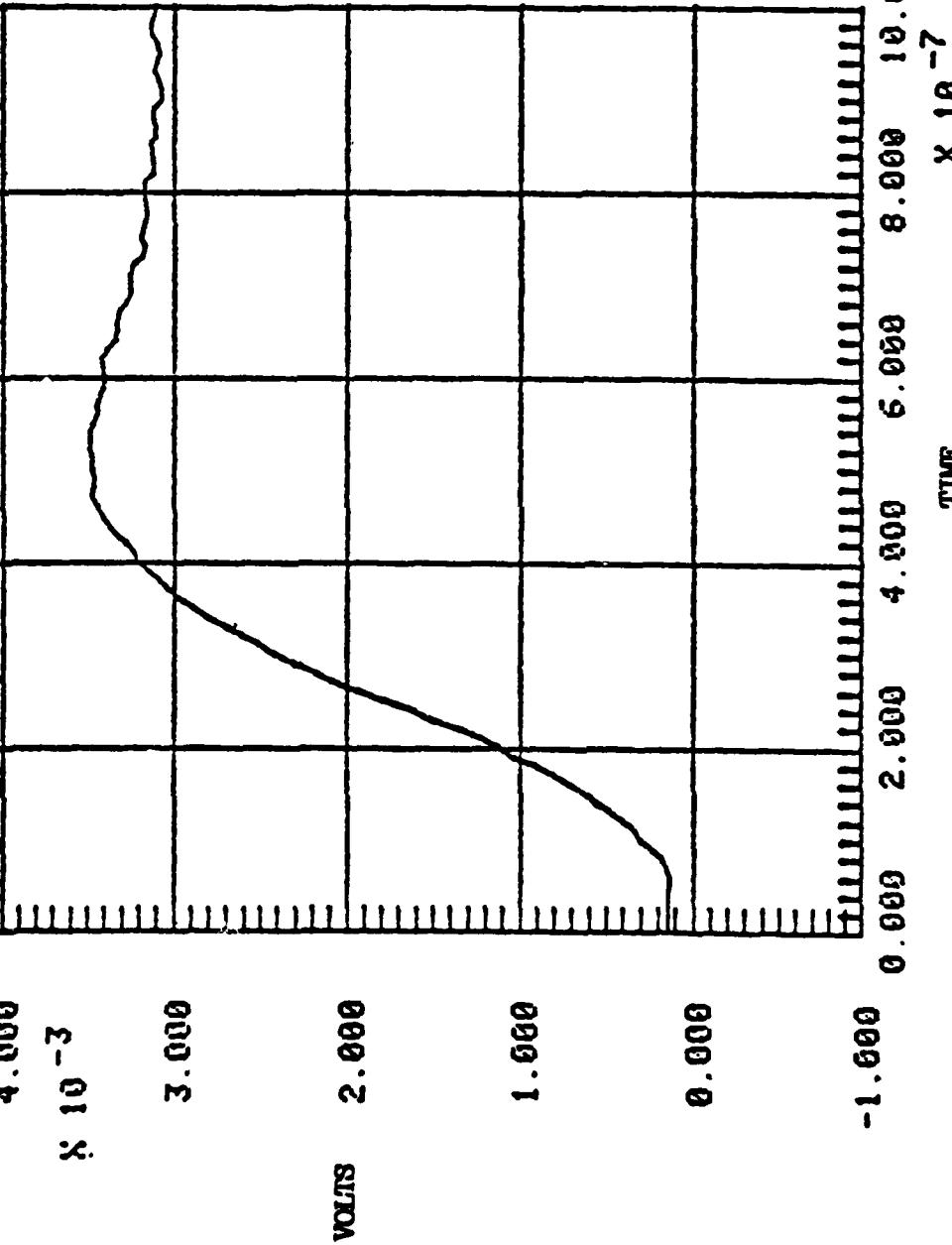
100 MA STEP

4.000×10^{-3}

VOLTS

1.000×10^{-3}

0.000×10^{-3}



POST-NEUTRON
OVERSHOOT ~ 11.3%
TEMPDC = 25°C
NR
NC

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APPENDIX 4.0

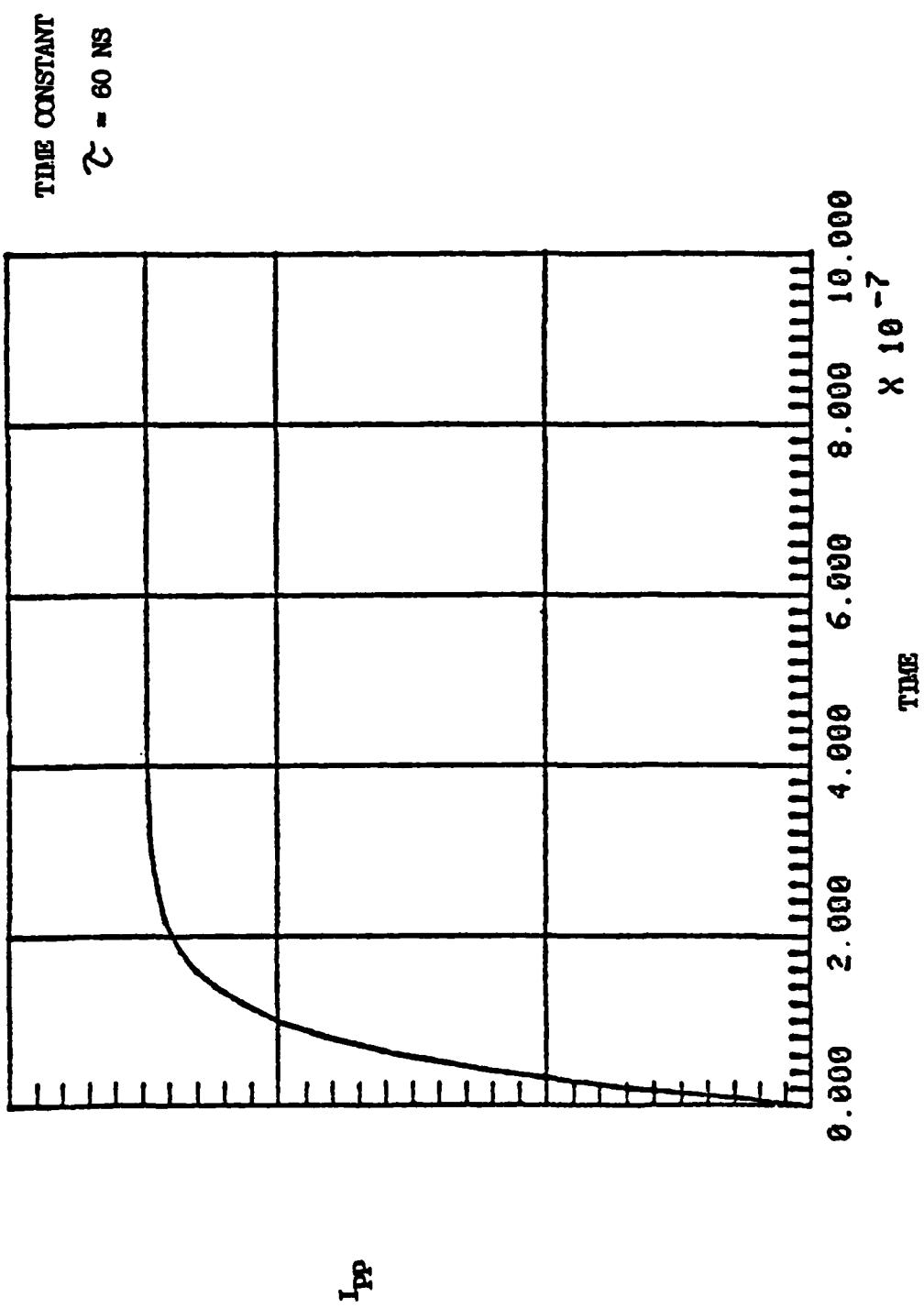
NOISE SIMULATIONS

4.1 TRANSIENT GAMMA

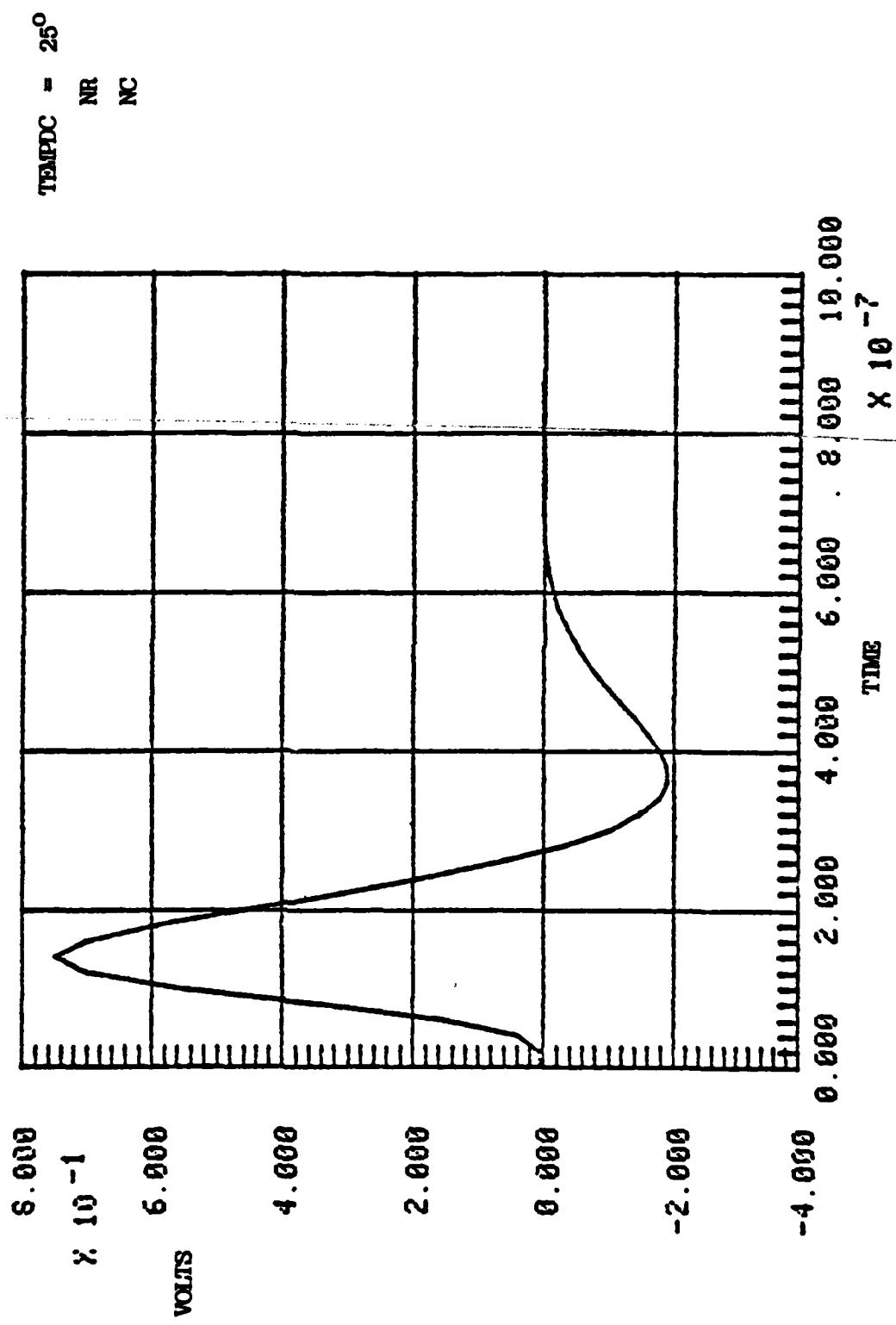
4.2 THERMAL NOISE

TYPICAL TRANSIENT GAMMA STEP

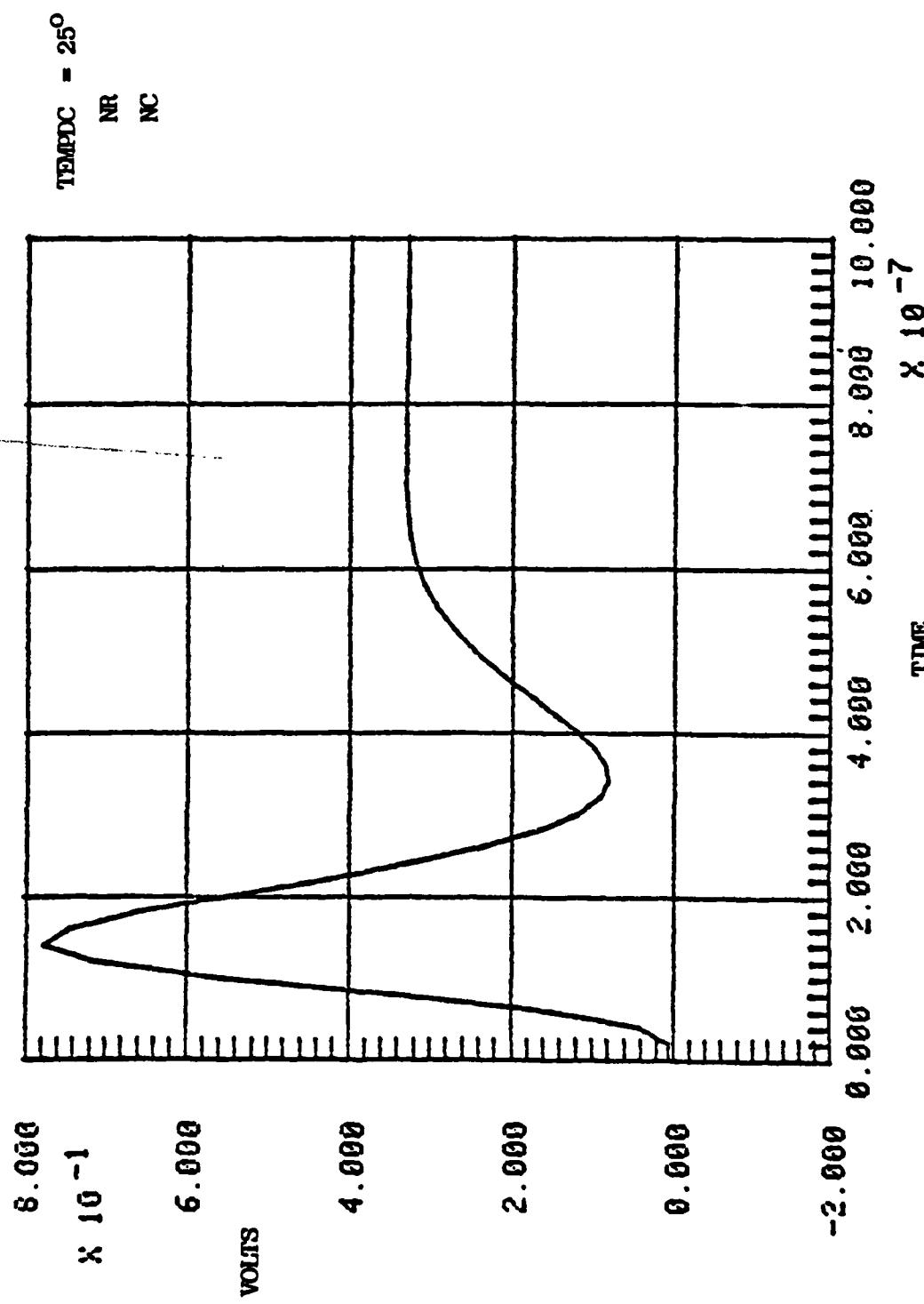
PHOTOCGENERATOR CURRENT



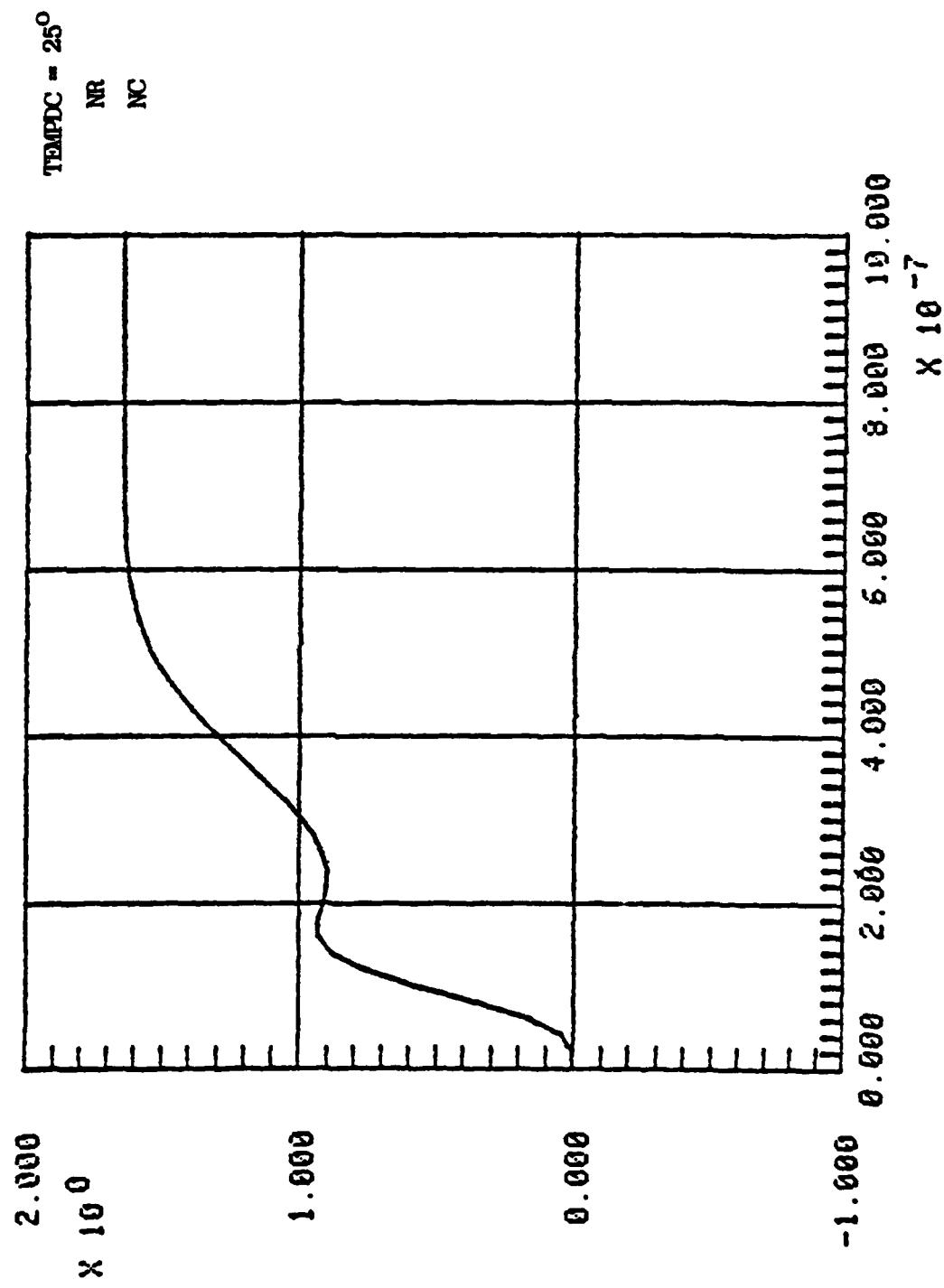
σ RESPONSE
(PERFECTLY MATCHED PHOTODIODE I_{pp})



γ RESPONSE
(1% MISMATCH IN PHOTODIODE I_{pp})



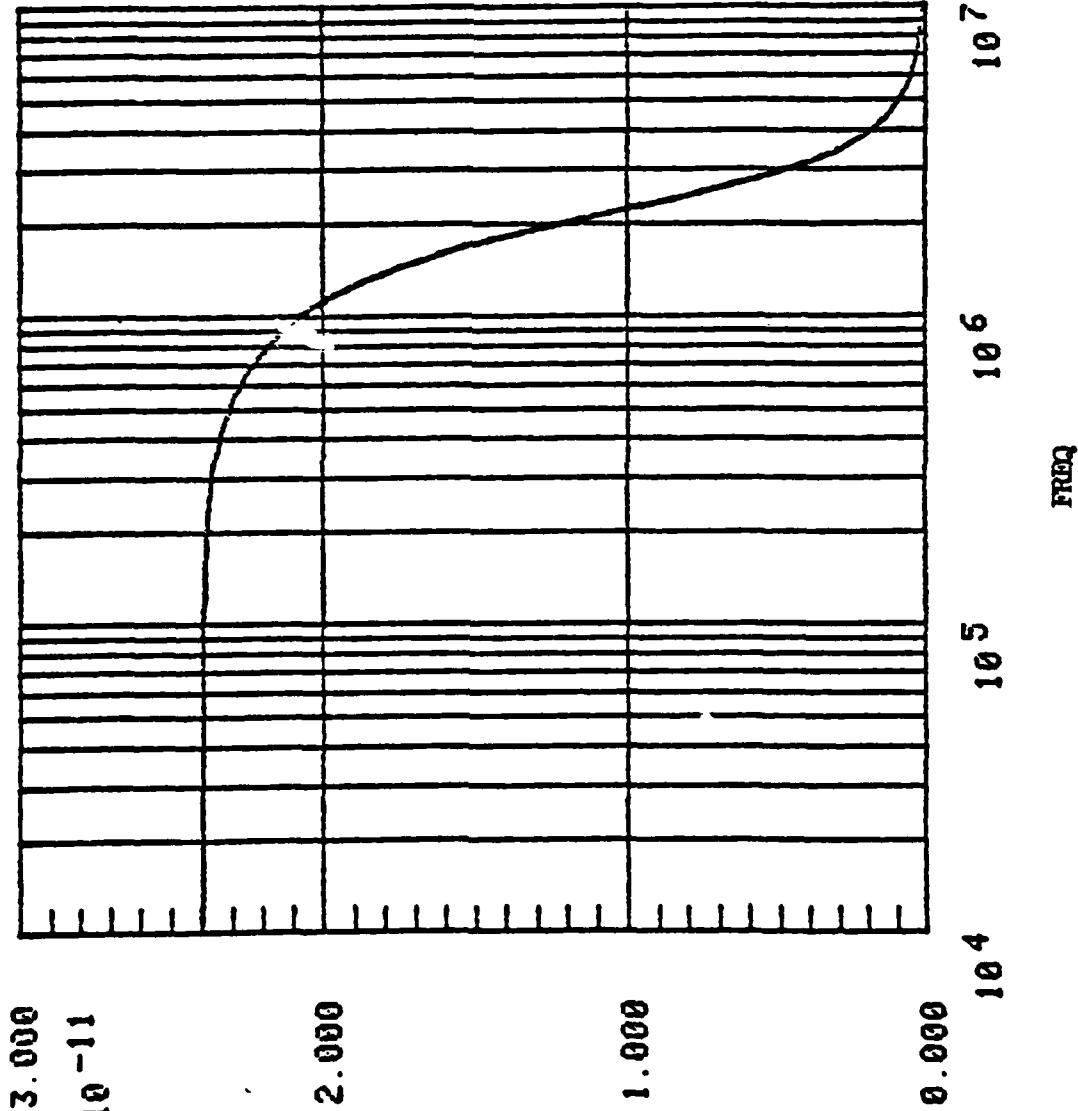
δ RESPONSE
(5% MISMATCH IN PHOTODIODE I_{PP})



OUTPUT THERMAL NOISE VOLTAGE SQUARED

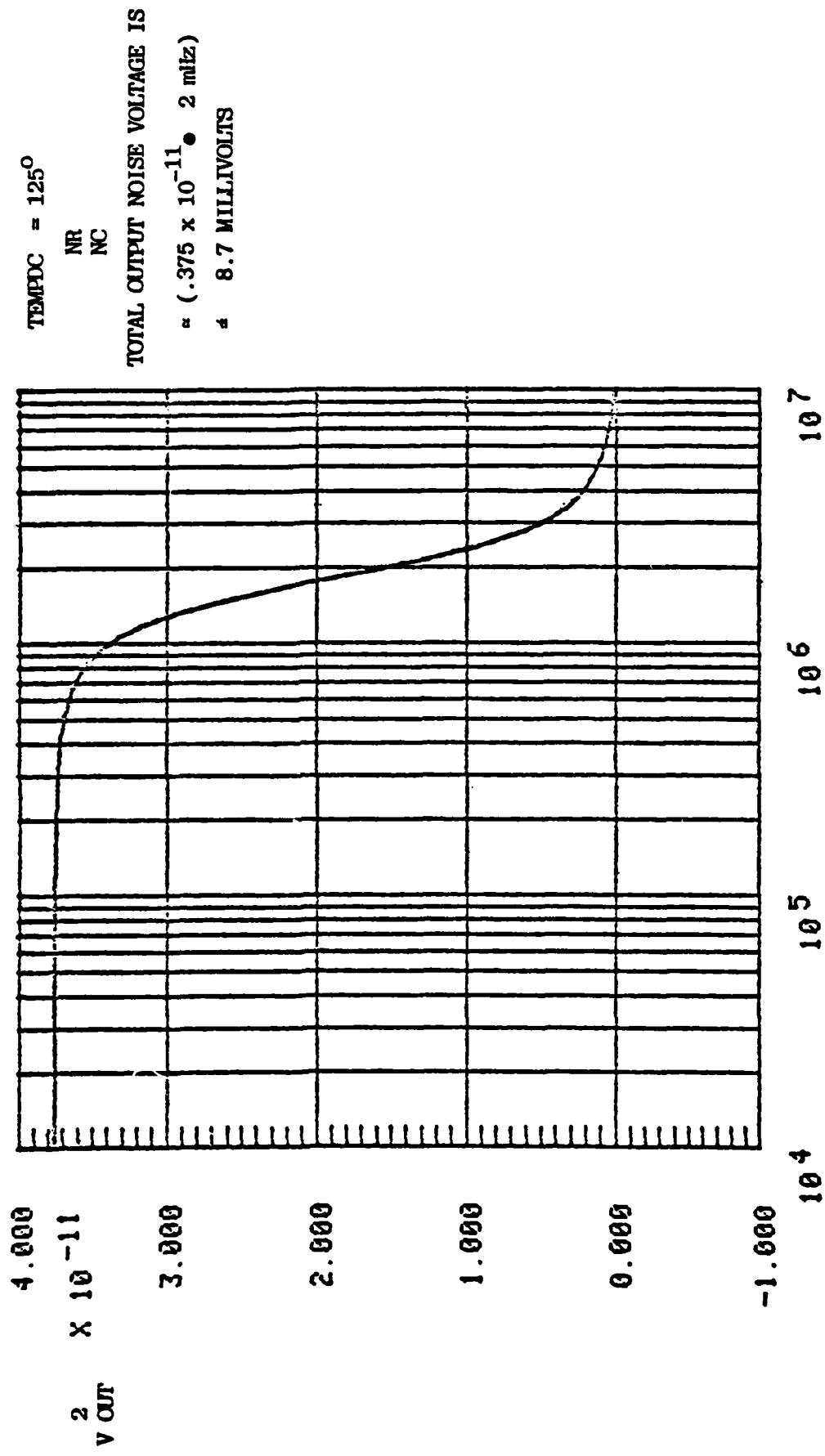
3.000
 $\times 10^{-11}$

v_{out}^2

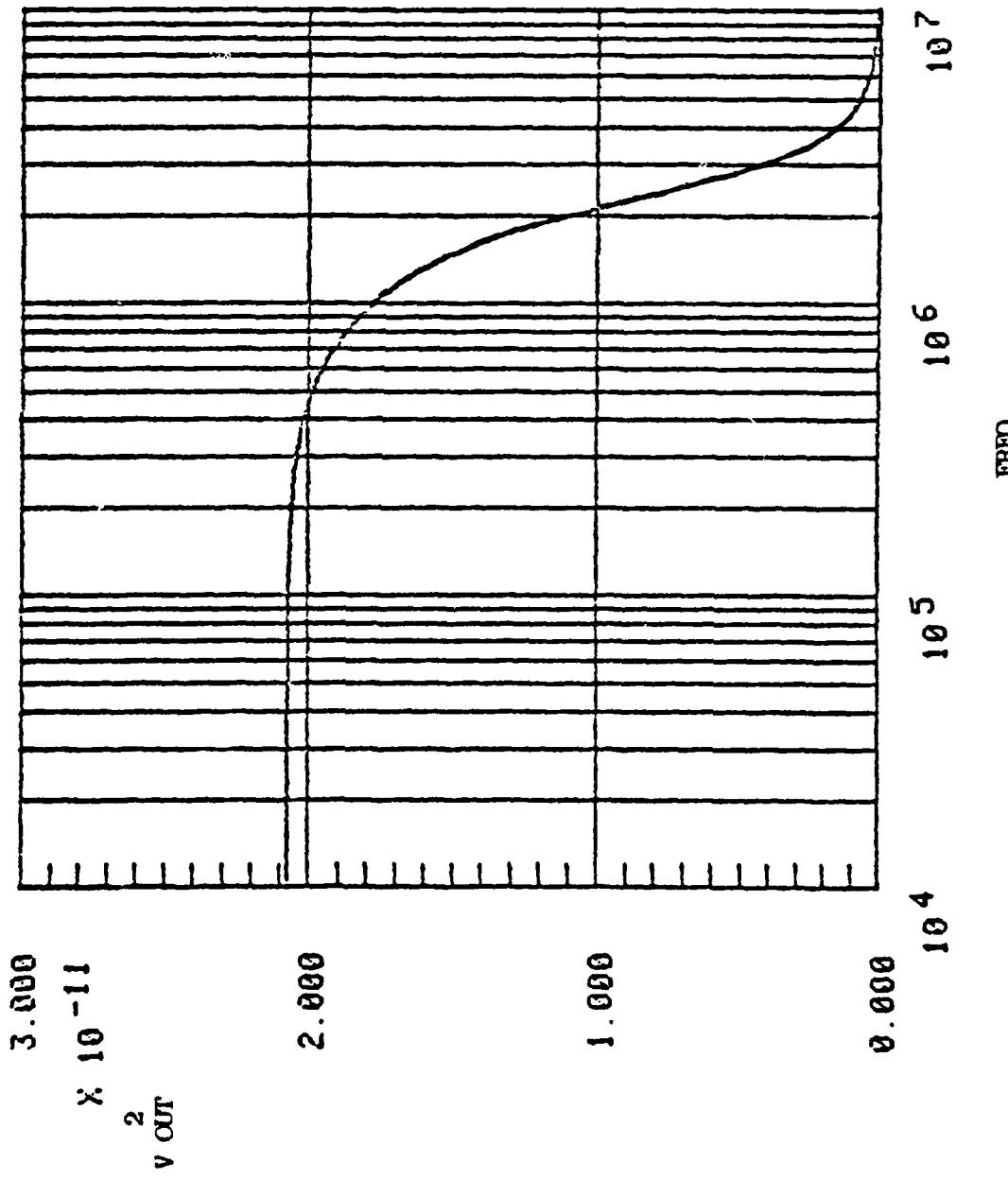


TEMPDC = 25°
NR
NC
TOTAL OUTPUT NOISE VOLTAGE IS
 $\approx (2.4 \times 10^{-11} \bullet 2 \text{ mHz})^{\frac{1}{2}}$
 $\approx 7 \text{ MILLIVOLTS}$

OUTPUT THERMAL NOISE VOLTAGE SQUARED



OUTWARD THERMAL NOISE VOLUME SQUARED



• $(2.07 \times 10^{-11} \text{ mW})^2$
TOTAL OUTWARD NOISE VOLUME IS
 6.5 MILLIWATS
NC
TEMDC = -55°

AD-A112 258

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F/6 9/1

DNA001-78-C-0356

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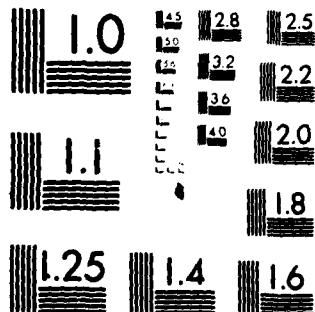
3rd
2nd
1st



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ATTN: J. Srour

Northrop Corp
ATTN: P. Gardner
ATTN: L. Apodaca
ATTN: Sec Ofc for T. Jackson

Pacific-Sierra Rsch Corp
ATTN: H. Brode

Physics International Co
ATTN: J. Shea
ATTN: Div 6000

R & D Associates
ATTN: S. Rogers
ATTN: P. Haas

Rand Corp
ATTN: C. Crain

Raytheon Co
ATTN: J. Ciccio

Ratheon Co
ATTN: A. Van Doren
ATTN: H. Flescher

RCA Corp
ATTN: G. Brucker
ATTN: V. Mancino

DEPARTMENT OF DEFENSE CONTRACTORS (Continued)

RCA Corp
ATTN: D. O'Connor
ATTN: Ofc N103

RCA Corp
ATTN: R. Killion

RCA Corp
ATTN: W. Allen

Rensselaer Polytechnic Institute
ATTN: R. Gutmann

Research Triangle Institute
ATTN: Sec Ofc for M. Simons, Jr

Rockwell International Corp
ATTN: V. Strahan
ATTN: V. De Martino
ATTN: V. Michel
ATTN: J. Bradford

Rockwell International Corp
ATTN: TIC BA08
ATTN: T. Yates

Rockwell International Corp
ATTN: D. Vincent

Sanders Associates, Inc
ATTN: L. Brodeur

Science Applications, Inc
ATTN: D. Long
ATTN: V. Verbinski
ATTN: J. Naber
ATTN: V. Ophan

Science Applications, Inc
ATTN: W. Chadsey

Science Applications, Inc
ATTN: D. Stribling

Singer Co
ATTN: J. Brinkman

Singer Co
ATTN: R. Spiegel

Sperry Rand Corp
ATTN: Engng Lab

Sperry Rand Corp
ATTN: R. Viola
ATTN: F. Scaravaglione
ATTN: C. Craig
ATTN: P. Maraffino

Sperry Rand Corp
ATTN: D. Schow

Sperry UNIVAC
ATTN: J. Inda

Spire Corp
ATTN: R. Little

DEPARTMENT OF DEFENSE CONTRACTORS (Continued)

SRI International

ATTN: A. Whitson
ATTN: B. Gasten
ATTN: P. Dolan

Sylvania Systems Group

ATTN: C. Thornhill
ATTN: L. Blaisdell
ATTN: L. Pauples

Sylvania Systems Group

ATTN: J. Waldron
ATTN: P. Fredrickson
ATTN: H. Ullman
ATTN: H & V Group

Systron-Donner Corp

ATTN: J. Indelicato

Teledyne Ryan Aeronautical

ATTN: J. Rawlings

Texas Instruments, Inc

ATTN: R. Stehlin
ATTN: A. Peletier

Texas Instruments, Inc

ATTN: F. Poblenz

TRW Systems and Energy

ATTN: G. Spehar
ATTN: B. Gililand

DEPARTMENT OF DEFENSE CONTRACTORS (Continued)

TRW Defense & Space Sys Group

ATTN: O. Adams
ATTN: A. Pavelko
ATTN: H. Holloway
ATTN: P. Guilfoyle
ATTN: R. Kingsland
ATTN: A. Witteles

TRW Defense & Space Sys Group

ATTN: W. Willis
ATTN: F. Fay
ATTN: R. Kitter
ATTN: M. Gorman

Vought Corp

ATTN: R. Tomme
ATTN: Library
ATTN: Tech Data Center

Westinghouse Electric Co

ATTN: L. McPherson

Westinghouse Electric Corp

ATTN: H. Kalapaca
ATTN: D. Crichti

